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TRANSACTIONS

OF THE

AMERICAN CERAMIC SOCIETY

VOLUME VII—PART I

Containing Papers and Discussions Read at the Meeting Held at Birmingham, Alabama, Jany. 30 and Feby. 1, 1905, With Some Other Contributions.

The Society is not, as an organization, responsible for the statements of facts or opinions expressed in its papers and discussions.

PUBLISHED BY THE SOCIETY
SECRETARY'S OFFICE, COLUMBUS, OHIO
APRIL 20, 1905

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OFFICERS.

For the Year Ending February, 1906.

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Term Expires, 1906.

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Term Expires, 1907.

WALTER M. FICKES, E. M., - - - Carnegie, Pa.

Term Expires, 1908.

HONORARY MEMBERS.

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FOREIGN MEMBERS.

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Barringer, Lawrence E., E. M. Schenectady, N. Y.	Research Chemist, General Electric Company.
Binns, Charles F., M. Sc., Alfred, N. Y.	Director New York State School of Clayworking and Ceramics.
Bleininger, Albert V., B. Sc., Columbus, Ohio.	Instructor in Ceramics, Ohio State University.
Burt, Stanley G., Cincinnati, Ohio.	Rookwood Pottery Company.
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Cushman, Allerton S., A.M., Ph.D., Washington, D. C.	Chemist Road Material Laboratory Department of Agriculture.
Fickes, Walter M., E. M., Carnegie, Pa.	Manager, Rosslyn Brick Company.
Fiske, J. Parker, B. S., 164 Devonshire St., Boston, Mass.	Fiske Brick Company.
Gates, William D., A. M. Chicago, Ill.	American Terra Cotta and Ceramic Company.
Geijsbeek, Samuel, Cheltenham, St. Louis, Mo.	Winkle Terra Cotta Company.
Gorton, Elmer E., 7-E. 42nd St., N. Y.	General Manager, W. A. Underhill Brick Company.
Hart, Edward, Ph. D., Easton, Pa.	Professor of Chemistry, LaFayette College.
Hensel, Otto, St. Louis, Mo.	Parker-Russel Mining and Manufacturing Company.
Hice, Richard R., E. M., Beaver, Pa.	Fallston Fire Clay Company.

Hottinger, Adolph F., Chicago, Ill.	Northwestern Terra Cotta Co.
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Langenbeck, Karl, 1434 Q St., Washington, D. C.	
Lovejoy, Ellis, E. M., Columbus, Ohio.	
Mayer, Ernest, Beaver Falls, Pa.	Mayer Pottery Company.
Minton, Leroy Hines, E. M., Mineral City, Ohio.	Fire Clay Works, C. Edward Holden.
Ogle, Earl, McK., Indianapolis, Ind.	United States Encaustic Tile Works.
Orton, Edward, Jr., E. M., Columbus, Ohio.	Director, Department of Ceramics, Ohio State University.
Parker, Lemon, St. Louis, Mo.	Parker-Russel Mining and Manufacturing Company.
Pass, James, Syracuse, N. Y.	Onondaga Pottery Company.
Peppel, Samuel Vernon, B. Sc., Louisville, Ky.	Editorial Staff, "Rock Products."
Purdy, Ross C., Columbus, Ohio.	Assistant in Ceramics, Ohio State University.
Richardson, Willard D., A. M., Columbus, Ohio.	Consulting Engineer to the Brick Industry.
Ries, Heinrich, Ph. D., Ithaca, N. Y.	Associate Professor of Economic Geology, Cornell University.
Stover, Edward C., Trenton, N. J.	Trenton Potteries Company.
Walker, Francis W., Beaver Falls, Pa.	Beaver Falls Art Tile Company.
Watts, Arthur S., Victor, N. Y.	Ceramic Engineer, The Locke Insulator Manufacturing Company.
Weelans, Charles, Trenton, N. J.	Supt'd Monument Pottery Co.
Wheeler, Herbert A., E. M., 3124 Locust St., St. Louis, Mo.	Consulting Engineer, Mining, Metallurgical and Ceramic Work.

FOREIGN ASSOCIATE MEMBERS.

Briegleb, Otto Wilh. Gustav, Amsterdam, Holland.	Manufacturer of Earthenware.
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Cieszewski, Joseph, Russian, Poland.	Prez. Grodzisk W. Henrykowie, gub Warszawska.
Cobb, John W., Leeds, Yorkshire, England.	Technical Assistant to Managing Director, Farnley Iron Company.
De Luze, Henri, Avenue de Poitiers, Limoges, France.	Ingenieur des Arts and Manufacture Theo. Haviland, Porcelain M'f'y.
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Jenkins, Newell Sill, D. D. S., Walpurgis, Strasse 15, Dresden, Germany.	Hofrath.
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Ludlow, Stephen H., Durham, Ontario, Canada.	Chemist, National Portland Cement Company.
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Page, Edwin Percival, Stourbridge, England.	Draughtsman, E. J. & J. Pearson's, Ltd.
Rauter, Dr. Gustav, Charlottenberg 4, Berlin.	Engineering Chemist.
Rix, Wilton Parker, 8 Kinglake Road, Egremont, Cheshire, England.	Consulting Chemist.
Rum Bellow, H. A., Leeds, England.	Chief Research Chemist, Leeds Fire Clay Company.
Sweet, George A., F. G. S., Brunswick, Victoria, Australia.	"The Close," Wilson St.
Thomas, Charles William, Pedmore, near Stourbridge, England.	Director, E. J. & J. Pearson, Ltd.

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Acheson, Edward Goodrich, Niagara Falls, N. Y.	Pres. Acheson Company.
Aldrich, John C., Pittsburg, Pa.	Star Encaustic Tile Company.
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Bauslog, Samuel Allen, Peru, Indiana.	Asst. Supt., Peru Electrical Manufacturing Company.
Bloomfield, Charles A., P. O. Box 413, Metuchen, N. J.	Dealer in Clays.
Booth, Thomas C., Perth Amboy, N. J.	Perth Amboy Terra Cotta Co.
Bowman, Robert K., Trenton, N. J.	Treas., Trenton Fire Clay & Porcelain Company.
Bowman, William, J. J., C. E., Trenton, N. J.	Trenton Fire Clay & Porcelain Company.
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Burr, Francis T., 150 Nassau St., New York.	Mgr., Richmond Kaolin Company.
Campbell, Augustine R., Tottenville, S. I., N. Y.	Atlantic Terra Cotta Company.
Clark, Thomas W., New Brunswick, N. J.	With National Pyrogranite Co.
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Colgan, Frank J., Grassy Point, N. Y.	Salesman for A. M. & W. H. Wiles, Manf. Clayworking Machinery.
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Coulter, Leonard Burnside, E. M., 130 W. Lane Ave., Columbus, Ohio.	With Prof. Orton, Jr., Manufacture of Pyrometric Cones.
Defebaugh, Edgar H., Louisville, Ky.	Editor and Publisher, "Rock Products."
Diedrick, William H., Salineville, Ohio.	Pres. and Gen. Mgr., The Dresden China Company.
Ellerbeck, Dr. Wm. Leon, Salt Lake City, Utah.	Doctor Dental Surgery.

Eskesen, Bennet K., Matawan, N. J.	Supt., New Jersey Mosaic Tile Company.
Eskesen, Thoge R., Matawan, N. J.	The New Jersey Architectural Terra Cotta Company.
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Evatt, Frank G., Paddock Bldg., Boston.	Dealer in Building Materials.
Ferguson, Silas M., Wellsville, Ohio.	United States Pottery Company.
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Galloway, William, 3215 Walnut St., Philadelphia, Pa.	Manufacturer of Terra Cotta.
Gates, Ellis Day, Terra Cotta, Ill.	American Terra Cotta and Ceramic Company.
Gates, William P., Terra Cotta, Ill.	American Terra Cotta and Ceramic Company.
Golding, Charles E., Trenton, N. J.	Mgr., William Golding Sons Co.
Gorsline, William Henry, 334 East Ave., Rochester.	Treas. and Mgr., Rochester Sewer Pipe Company.
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Gray, Thomas, East Boston, Mass.	New England Pottery Company.
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Hamilton, Percy C., 326 Fourth Ave., Pittsburg.	Manufacturer Sewer Pipe.
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Hardy, Isaac Ernest, Momence, Ill.	Supt., Tiffany Enameled Brick Company.
Hasburg, John W., 588 Fullerton Ave., Chicago.	Dealer in Ceramic Materials.
Hasslacher, Jacob, 100 William St., New York.	Roessler and Hasslacher Chemical Company.
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Haugh, B. O., Anderson, Ind.	Manager, National Tile Company, Columbia Plant.
Haugh, Harry, Anderson, Ind.	Supt., National Tile Company, Columbia Plant.
Hemphill, Wm. J., 5200 Manchester Ave., St., Louis, Mo.	Gen'l Manager, Evans and Howard Firebrick Manufacturing Co.
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Holmes, Carl Gilbert, 1463 N. High St., Columbus, O.	Student Ceramic Department, Ohio State University.
Hope, Herford, Beaver Falls, Pa.	Asst. Foreman, Mayer Pottery Company.
Humphrey, Harrold P., E. M., Trenton, N. J.	Ceramic Chemist, Cook Pottery Co.
Kendrick, J. Lucius S., Saginaw, Mich.	Student Ceramic Department, Ohio State University.
Koch, Charles Frederich, Covington, Ky.	Cambridge Tile Manufacturing Co.
Koch, Julius J., Shawnee, Ohio.	Supt., Iron Clay Brick Co.
Krehbiel, Junius F., B. Sc., 108 Holland St., Syracuse, N. Y.	
Kwiatkowski, Louis F., 114 Liberty St., New York.	Civil and Mining Engineer, with H. Huennekes & Co.
Landers, William Franklin, Indianapolis, Ind.	Supt., U. S. Encaustic Tile Works.
Layman, Frank Edward, Columbus, Ohio.	Student Ceramic Department, Ohio State University.
Linderoth, Sven, Chicago, Ill.	Alhambra Ceramic Works.

Lindley, Jacob, 128 S. Olden Ave., Trenton, N. J.	Foreman, The Ideal Pottery Co.
Locke, Frederick M., Victor, N. Y.	Manufacturer Porcelain Insulators.
Loundes, William Bladen, Mt. Savage, Md.	Supt. Mt. Savage Fire Brick Company.
Maddock, Archibald M., Trenton, N. J.	Thomas Maddock & Sons.
Maddock, Thomas, Trenton, N. J.	John Maddock & Sons.
Maddock, John, Trenton, N. J.	John Maddock & Sons.
Mandle, I., St. Louis, Mo.	Miner and Shipper of Pottery Clay.
McBean, Athole, 3943 Pine St., San Francisco, Cal.	Secy. and Treas., Gladding, McBean & Company.
McCaffery, Richard, Stanislaus, 182 Broadway, N. Y.	Consulting Engineer, Shawmut Clay Manufacturing Co.
Meakin, Robert J., E. Liverpool, Ohio.	Mgr., Hall China Company.
Middleton, Jefferson, Washington, D. C.	Statistician, United States Geological Survey.
Morris, W. C., St. Louis, Mo.	Vice-Pres. and Gen. Mgr., Christy Fire Clay Company.
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Ogan, Mark, 5801 Manchester Ave., St. Louis, Mo.	St. Louis Terra Cotta Company.
Ogden, Ellsworth, 106 Price St., Columbus, O.	Student, Ohio State University, Ceramic Department.
Parmelee, Cullen W., B. Sc., New Brunswick, N. J.	Director, Dept. Ceramics, Rutger's College.
Phillips, William, South San Francisco, Cal.	Supt'd Steiger Terra Cotta and Pottery Company.
Plant, Alfred, Keyport, N. J.	Eagle Tile Company.
Pope, Charles A., Trenton, N. J.	Trenton Fire Brick Company.
Porter, Alfred S., 1226 Ansel Ave., Chicago, Ill.	Editor Glass & Pottery World.
Post, Malcolm P., St. Louis, Mo.	Foreman, Blackmer & Post, Sewer Pipe Company.

Powell, William H., New York, N. Y.	Excelsior Terra Cotta Company.
Preston, Francis C., Cleveland, O.	Sales Agent, Dover Fire Brick Co. 509 Cuyahoga Bldg.
Purington, Dilwyn V., Chicago, Ill.	Pres., Purington Paving Brick Co. Chamber of Commerce Bldg.
Ramsey, Andrew, Mt. Savage, Maryland.	Mt. Savage Enameled Brick Co.
Randall, Theodore A., Indianapolis, Ind.	Editor "Clay-worker."
Raynolds, Edwin William, Columbus, Ohio.	Student Ceramic Department, Ohio State University.
Rea, William J., Buffalo, N. Y.	Supt., Buffalo Pottery Company.
Rhodes, William Albert, E. Liverpool, Ohio.	Vice-Pres., Colonial Company.
Riddle, Frank Harwood, 185 W. 9th Ave. Columbus, O.	Student Ceramic Department, Ohio State University.
Robineau, Samuel E., Syracuse, N. Y.	Editor "Keramic Studio."
Robinson, Edward Wanton, Hartford, Conn.	Gen. Mgr., Hartford Faience Co.
Roessler, Franz, 100 William St., New York	Vice-Pres. and Supt., Roessler & Hasslacher Co.
Rowe, John, Zanesville, Ohio.	Asst. Supt., American Encaustic Tiling Company.
Royse, Daniel, 45 Plymouth Place, Chicago.	Man. Editor, Windsor & Kenfield Publishing Company.
Russell, Joseph, 1302 Queen St., E. Toronto, Can.	Brick Manufacturer.
Sant, John, E. Liverpool, Ohio.	Clay Salesman, Miner and Broker.
Schoedel, J. A. W., St. Louis, Mo.	Supt., Christy Fire Clay Co.
Simpkins, Ralph, St. Louis, Mo.	Mgr., Union Pressed Brick Works.
Singer, Lewis P., Lincoln, Cal.	Chemist, Gladding, McBean & Co.
Skeele, H. B., Chicago, Ill.	Ludowici Roofing Tile Company.
Smith, Amedee M., Portland, Oregon.	Western Clay Manufacturing Co.

Speir, Oswald, Perth Amboy, N. J.	Asst. Gen. Mgr., Perth Amboy Terra Cotta Company.
Staley, Homer Francis, 73 E. 8th Ave., Columbus, O.	Student Ceramic Department, Ohio State University.
Stamm, John, East Liverpool, Ohio.	General Manager National China Company.
Stanbery, George A., Zanesville, Ohio.	American Encaustic Tile Company, Ltd.
Stull, Ray, Elkland, Pa.	
Stowe, Charles B., Cleveland, Ohio.	The Stowe-Fuller Company.
Taylor, William Watts, Cincinnati, Ohio.	President Rookwood Pottery Co.
Thomas, David C., Wellsville, Ohio.	United States Pottery Company.
Thrall, Charles U., Tottenville, S. E., N. Y.	Supt., Atlantic Terra Cotta Co.
Townsend, Everett, Morrisville, Pa.	National Tile Company.
Trommer, Carl E., 100 William St., New York.	Roessler & Hasslacher Chemical Company.
Tweedy, Edward P., West Cornwall, Conn.	Clay Miner.
Volz, William J., St. Louis, Mo.	Supt., Evans & Howard Fire Brick Company.
Wagner, Fritz, Chicago, Ill.	Northwestern Terra Cotta Co.
Walker, John A., Jersey City, N. J.	Joseph Dixon Crucible Company.
Welch, John H., St. Louis, Mo.	The Mound City Roofing Tile Co. 3235 Morganford Road.
Whitehead, C. Louis, Trenton, N. J.	Providential Tile Works.
Williams, Ira A., B. S., Ames, Iowa.	Geological Department, Iowa State College.
Wolf, George, Marshalltown, Iowa.	Supt., Marshalltown Pottery Co.
Worcester, Wolsey Garnet, Groveport, Ohio.	Gen. Mgr., Central Ohio Roofing Tile and Brick Co.
Yates, Alfred, Johnsonburg, Pa.	Johnsonburg Vitrified Brick Co.
Young, George F., Zanesville, Ohio.	Mgr., Roseville Pottery Co.
Youngren, Peter Lewis, 261 15th St., Milwaukee, Wis.	Kiln Builder and Burner.

SECRETARY'S ANNUAL REPORT.

To the Members and Associates
of the American Ceramic Society.

Gentlemen:—I have the honor to report to you for your information the following facts connected with the Society's business for the year 1904-05:

I. International Meeting of Ceramic Societies.

According to the instructions of the Society, I entered into correspondence with the representatives of the Ceramic Societies of England and Germany, trying to manage a date at which all three organizations could get together at St. Louis, and offering to do our utmost to further their pleasure in this country. The English Society replied promptly through its secretary, Mr. W. Jackson, but they would hold out no hopes of enough of their members coming over at any one time to make a company. The German Society made no official reply, but their secretary informed me that the invitation had been turned over to a gentleman who had undertaken to organize a personally conducted excursion of German clayworkers, members of the society and others, to St. Louis. The affair was not official, but was carried on partly or indirectly under their auspices. The conductor of the party charged a flat fee for the transportation, meals, and services in securing entree to plants, etc.

The action of the secretary of the German society in turning a message of hospitality and good fellowship from one society to another, over into the hands of an individual, to be exploited for this individual's private gain, seemed to me to evince either a great misunderstanding of the facts in the case, or else a very unpardonable lack of delicacy in view of the friendly character of the message. There was not time to protest against this unwarrantable transfer of the invitation before the date of the sailing of the German excursion, except by cable, which was not thought worth while. When the excursion reached this country, the conductor wrote to your secretary and possibly others, seeking aid in arranging an itinerary and in obtaining access to plants. Notwithstanding the objectionable course which the whole matter had taken, a polite reply was made, willingness to co-operate was shown, and information was sought as to how best to help them. The receipt of this letter was never acknowledged and the party never came to Columbus, nor does the secretary know of their ever having called elsewhere. If they made the trip as a body, it was managed very quietly, and without making themselves known to the society or its members in such a way as to permit or invite

the extension of any civilities to them. Our society has acquitted itself well in the matter. It has shown a friendly and courteous disposition to meet and to aid its foreign visitors, and the failure of the plan was not its fault.

Notwithstanding the failure of this official invitation, there were some foreign visitors of distinction who were received by members of the society, and passed from member to member with letters and notes, to their great convenience and pleasure. Among these were Mr. W. Jackson, A. R. C. S., Secretary of the English Ceramic Society and Head of the Ceramic School in Victoria Institute, Tunstall, England, Dr. W. Pukall, Head of the Ceramic School at Bunzlau, Germany, Henri DeLuze, of Limoges, France, connected with the porcelain industry of that place, Nils Fredricksson, of Svedala, Sweden, Head of the Swedish Brick Makers School, Dr. S. Doi, President of the Technological School at Nagoya, Japan, Dr. N. S. Jenkins, connected with the porcelain industry of Dresden, Germany, and a few others. In most cases, these gentlemen came into intimate touch with the membership of the Society, and were pleased to ally themselves with it as associate members. The effort to cement the relations of the American Ceramic Society with those working on the same lines abroad, has therefore not wholly failed.

II. Inventory of Transactions.

Pursuant to the orders of the Society, the secretary has caused an inventory of the Transactions now left on hand and available for sale to be made, with the following results, on December 10, 1904:

Vol. I	312
Vol. II	204
Vol. III	303
Vol. IV	230
Vol. V	251
Vol. VI	234
	1534

This statement is not now entirely correct, owing to recent sales, especially of the manual. The value may be taken roughly at $3.00 each, as sales are made at $4.00 to non-members, and from 50 cents to $2.00 to members. This makes a valuation of well over $4,500 on hand.

III. Insurance of Transactions.

The secretary has insured the volumes in his care in the sum of $2,000, at $1.05 per 100, or $21.00 per annum. They are stored at 1538 North High Street, in a brick building, well protected from fire and damp, in a room which is kept constantly locked, and which contains no other materials.

IV. Summer Meeting.

The Summer Meeting took place at St. Louis, September 5th to 10th, inclusive. According to programme, the meeting was wholly social, consisting of a noon-day lunch and reunion hour daily. There was also, on September 9th, a dinner at the Tyrolean Alps, in which the visiting members and the resident members of St. Louis and vicinity made up a party. These occasions were of the most pleasurable character. There were no papers, or formal exercises of any sort. A register was kept for all who attended any of these meetings to sign, and this record discloses the following persons as having attended: Messrs. Ries, Ogden, Wheeler, Orton, Taylor, Geijsbeek, Parker, Richardson, Gates, Williams, Randall, Ellerbeck, Bowman, W. J. J., Bowman, R. K., Whitehead, Lovejoy, Walker, Mandle, Grady, Mrs. Kalb, Fickes, Hottinger, Koch, Binns, Volz, Hensel, Stover, and Burt, together with Dr. Pukall, M. DeLuze, Ingenieur Bohumil of Praque, Austria, and a few other visitors. Total registration at the meeting thirty-six, though not more than fifteen or twenty were assembled at any one time. It was the sentiment of those in attendance that the meetings did undoubted good, in keeping up the custom of a summer meeting of the society, at a time when none could have been held elsewhere or in any other way.

V. Growth in Membership.

The growth in membership continues most satisfactory. Since the last meeting, there have been two letter ballots taken, resulting in the election of the following gentlemen:

Bauslog, S. A., Ass't Supt., Peru Electrical Mfg. Co., Peru, Ind.

Cieszewski, J., Russian Poland.

Conkling, Ira L., Pres. Conkling-Armstrong Terra Cotta Company, Philadelphia, Pa.

Fredriksson, Nils, Director of Ceramic School at Svedala, Svedala, Sweden.

Grady, Robt. F., Mgr. St. Louis Terra Cotta Co., St. Louis, Mo.

Harker, H. N., Gen'l Mgr., Harker Pottery Co., East Liverpool, O.

Jenkins, Newell Sill, D. D. S. & K. S. Hofrath, Walpurgis Str. 15, Dresden, Germany.

Jones, Benj., Pres. Jones Fire Brick and Cement Company, 54 Atlas Bank Building, Cincinnati, Ohio.

Loundes, William Bladen, Supt. Mt. Savage Fire Brick Company, Mt. Savage, Md.

Luze, De, Henri, Avenue de Poitiers, Limoges, France.

Minton, Roy H., Mineral City, Ohio.

Rhodes, Wm. Albert, Knowles, Taylor & Knowles Company, East Liverpool, Ohio.

Royse, Daniel, Managing Editor, Windsor & Kenfield Pub. Co., 45 Plymouth Place, Chicago, Ill.

Singer, Lewis P., Chemist, Gladding, McBean & Co., Lincoln, Cal.

Volz, W. J., Supt., Evans & Howard Fire Brick Co., St. Louis, Mo.

Wolfe, George, Supt., Marshalltown Pottery Co., Marshalltown, Ia.

And in the ballot of December 1st, 1904:

Thomas W. Clark, 809 Donally St., Charlestown, W. Va.

John V. Cobb, Assistant to Director, Farnley Iron Co., Leeds, England.

Robert J. Meakin, East Liverpool, Ohio, Manager of the Hall China Company.

Total number of mid-year elections 19.

There are always some members in arrears in their dues, and others who expect to drop out but who have not formally done so, so that it is difficult to give you an absolutely accurate count. The roll of the society is now as follows, as nearly as can be ascertained:

Honorary members	1
Members.	
Resident	29
Foreign	1
Associates.	
Resident	119
Foreign	16
	166

Some of these will probably not pay their arrears of dues, but as there are now on hand a number of new applications for membership awaiting action, we are safe in saying that the membership at this meeting is not less than 170. The growth of the society, calculated in percents of its first year's membership, has been as follows:

Year	1900	1901	1902	1903	1904
Percentage Gain	100	78	82	85	143

The above shows a very healthful condition in the Society, and it is hoped that the gains may continue as hitherto.

Very respectfully submitted,

EDWARD ORTON, JR.,
Secretary.

REPORT OF TREASURER.

Members of the Ceramic Society.

Gentlemen:—It gives me great pleasure to present to you my sixth annual report.

During the past year we have almost trebled our balance, and now have a comfortable balance of nearly six hundred dollars. While this sum is in the main due to a reduction in our expenses, still receipts have held up well, and I feel that the Society is rapidly approaching an assured financial position.

Thanking you for the honor conferred upon me, I beg to respectfully submit the following report:

RECEIPTS.

From Dues

Balance brought forward from 1903-1904	$200.41	
29 Members	165.00	
116 Associates	620.21	785.21
Sales of Publications.		
16 Vol. I	24.70	
16 Vol. II	41.20	
16 Vol. III	27.20	
18 Vol. IV	41.20	
21 Vol. V	62.80	
5 Vol. VI	19.20	
38 Manual	37.20	250.50
Net profits on 53 Vols. Seger		107.72
Old accounts received		21.50
Payments made in advance		39.17
Total receipts		1407.52

DISBURSEMENTS.

Preparation of Volume VI.

Hann & Adair, Printers	$538.02
Bucher Engraving Company	41.81
T. E. French, for drawing charts	13.00
By Secretary	1.75
Mrs. B. A. Kalb, Official Stenographer	139.00

Secretary's Office.

Stenographer	11.35
Telegrams	2.26
Express	11.80
General	3.66

Treasurer's Office.

Stenographer	16.25
Printing	4.00
Total disbursements	791.90
By payments made in advance	39.17
By balance on account 1904-1905	576.45
Total	1407.52
Gross balance forward	615.62

S. G. BURT, Treasurer.

Birmingham, Ala., January 31, 1905.

The undersigned auditors report that they have examined the accounts and vouchers of Stanley G. Burt, Treasurer, and find the same correct, and the balance, $576.45, in his hands as treasurer, and the Society is to be congratulated on the carefulness and efficiency of its treasurer.

R. R. HICE.
R. K. BOWMAN.

RULES.

OBJECTS.

The objects of the American Ceramic Society are to promote the arts and sciences connected with Ceramics by means of meetings for social intercourse, for the reading and discussion of professional papers, and for the publication of professional literature.

MEMBERSHIP.

The Society shall consist of Honorary Members, Members and Associates.

Honorary Members must be persons of acknowledged professonal eminence, and shall not exceed five in number.

Members shall be persons competent to fill responsible positions in Ceramics and have suitable qualifications.

Associates shall include persons interested in Ceramics and the allied arts.

Honorary Members shall be proposed by at least five members, approved by the Council, and receive at least 90 per cent. of the votes cast by letter ballot at the annual meeting.

Members and Associates shall be proposed by at least three Members or Associates, approved by the Council, and receive at least 75 per cent. of the votes cast by letter ballot. A candidate for admission must make application on a form prepared by the Council which shall contain a written statement of his age, professional experience, and that he will, if elected, conform to the laws, rules, and requirements of the Society.

All Honorary Members, Members and Associates shall be equally entitled to the privileges of membership, except that only Members shall be entitled to hold office and to vote. Applicants for a change in grade of membership shall conform to the requirements of a new applicant.

Any person can be stricken from the membership of the Society on the request of five or more Members, on the recommendation of a majority of the Council, if he fails to resign on the advice of the Council. Such person, however, shall first be notified of the charges against him, and be given a reasonable time to appear before the Council, or present written defense, before final action is taken by the Council.

DUES.

Honorary Members shall be exempt from all dues.

The iniation fee of Members shall be ten dollars, and of Associ-

ates five dollars, which if not paid within six months after election, will render the election void.

The annual dues for Members will be fixed by the Council, but shall not exceed five dollars per year.

The annual dues for Associates will be fixed by the Council, but shall not exceed four dollars per year.

Any Member or Associate in arrears for over one year may be suspended from membership by the Council until such arrears are paid.

OFFICERS.

The affairs of the Society shall be managed by a Council, consisting of a President, Vice President, Secretary, Treasurer, and three Managers, who shall be elected from the members at the annual meeting, and hold office until the adjournment of the meeting at which their successors are elected.

The President, Vice President, Secretary and Treasurer shall be elected for one year, and the Managers for three years; and no President, Vice President, or Manager shall be eligible for immediate re-election to the same office.

The duties of all officers shall be such as usually appertain to their offices, or may be delegated to them by the Council or the Society; and the Council may at its discretion require bonds to be furnished by the Treasurer.

Vacancies in any office shall be filled by appointment by the Council, but the new incumbent shall not thereby be rendered ineligible to re-election at the next annual meeting to the same office. On the failure of any officer to execute his duties within a reasonable time, the Council, after duly warning such officer, may declare the office vacant, and appoint a new incumbent.

A majority of the Council shall constitute a quorum; but the Council shall be permitted to carry on such business as it may desire by letter.

ELECTIONS.

At the annual meeting, a nominating committee of five Members, not officers of the Society, shall be appointed, and this committee shall send the names of nominees to the Secretary at least 60 days before the annual meeting, who shall immediately forward the same to the Members. Any other five members may also present the names of any candidates to the Secretary, provided it is done at least 30 days before the annual meeting. The names of all candidates, provided their assent has been obtained, shall be placed on the ballot without distinction as to nomination by the regular or an independent nominating committee, which shall be mailed to every member, not in arrears, at least 20 days before the annual meeting. The ballot shall be inclosed in an inner blank envelope, and the outer envelope shall be endorsed by the voter. and mailed to the

Secretary for collection. The blank envelopes shall be opened by three Scrutineers appointed by the Chair at the annual meeting, who will report the result of the election. A plurality of the votes cast shall elect.

MEETINGS.

The annual meetings shall take place at such time and place as the Council may decide, at which time reports shall be made by the Council, Treasurer, and Scrutineers of election, and the accounts of the Treasurer, audited by a committee of three appointed by the Chair.

Other meetings may be held at such times and places during the year as the Council may decide, but at least 20 days' notice shall be given of such meetings.

Seven members shall constitute a quorum at any regular meeting, and a majority shall rule, except where otherwise specified.

The order of business at the annual meeting shall be:—

1. Reading of Minutes of last meeting.
2. Reports of the Council and Treasurer of the Society.
3. Announcement of Election of Members.
4. Announcement of Election of Officers.
5. Appointment of Nominating Committee.
6. Old Business.
7. New Business.
8. Reading of Papers.

PUBLICATIONS.

The Council shall act as a Publication Committee, and decide as to what to publish. The publications of the Society shall be sent to all Members and Associates not in arrears. The Secretary will furnish each author with reprints of his papers at cost price, provided due notice is given that reprints are desired.

The Society is not, as a body, responsible for the statements or opinions expressed in its publications.

PARLIAMENTARY STANDARD.

Roberts' "Rules of Order" shall be the parliamentary standard on all points not covered by these rules.

AMENDMENTS.

These rules may be amended at any regular meeting by a two-thirds vote of a letter ballot at the subsequent annual meeting, provided a written notice of such proposed change is sent to each member at least 30 days before said annual meeting. Said proposed amendments shall be printed on the ballot for officers and counted by the same Scrutineers.

PUBLICATIONS.

The publications of the Society are as follows:

	Description of Volume.	Price to Members.	Price to Others.
Vol. I.	Transactions for 1899, 110 pages, bound in paper,	$0.50	$4 00
Vol. II.	Transactions for 1900, 278 pages, bound in paper,	2.00	4.00
Vol. III.	Transactions for 1901, 230 pages, bound in paper,	1.00	4.00
Vol. IV.	Transactions for 1902, 300 pages, bound in paper,	1.50	4.00
Vol. V.	Transactions for 1903, 420 pages, bound in paper,	2.00	4.00
Vol. VI.	Transactions for 1904, 287 pages, bound in paper,	1.50	4.00
Manual of Ceramic Calculation (continued in Vol. II as a part thereof,) 86 pages, bound in paper,		1.00	1.00
The Collected Writings of Dr. Hermann August Seger, Volume I. Contains (A) Treatises of a general scientific nature, (B) Essays relating to Brick and Terra Cotta, Earthenware and Stoneware, and Refractory Wares. Pages, 552. Bound in cloth.		7.50	7.50
The Collected Writings of Dr. Hermann August Seger, Volume II. Contains (B) Essays on Whiteware and Porcelain. (C) Travels, Letters and Polemics. (D) Uncompleted works, and extracts from the archives of the Royal Porcelain Factory. Pages, 605. Bound in cloth,		7.50	7.50
Cost of full set, not including manual.....		24.50	29.00

At the Cincinnati meeting, the council fixed a sliding scale of prices to apply to the sale of volumes of the Transactions, when the number unsold falls below 200 copies. As the copies become scarcer, prices will be increased to both members and others. The supply of

four of the volumes has already fallen close to 200 copies, and is diminishing steadily, and will probably pass below this mark during the coming year. Members and Associates who do not yet own full sets are advised to procure them at once.

At the same meeting the following resolution was adopted:

Resolved, that the custom by which members and associates may obtain copies of the Transactions at reduced or so-called "members rates," is intended only to enable each person to obtain one complete file of the transactions.

The necessity of this resolution arose from the expressed desire of a member to buy a copy of the transactions, with the intent to sell it to a friend for whom he wished to save the additional price charged to non-members. In accordance with the spirit of this resolution. the Treasurer will not supply more than one copy of a volume to a member at reduced rate, except when loss or destruction of a volume gives good cause for so doing.

At the same meeting, it was ordered that the Secretary should insure the copies of the Transactions still in his care, which has been done in the sum of $2,000.

Every member or associate receives one copy of the Transactions free for each year for which he pays dues. He is entitled to purchase copies for the years antedating his connection with the Society at the costs indicated in the first column. All others can obtain copies at the prices listed in the second column by sending order, accompanied with check. to

STANLEY G. BURT,
Care of Rookwood Pottery Co.,
Cincinnati, Ohio.

PREFACE.

Under the policy adopted by the Society at the Seventh Annual Meeting, at Birmingham, Ala., the Transactions are to be published in quarterly installments. It is intended to cover the papers read at the meeting in the first three parts, leaving the fourth part for the publication of important new papers, in advance of the Annual Meeting, thus making possible a more thorough discussion. As there is no decided tendency towards sending in papers, in advance, no fear need be entertained that the fourth installment will be over-crowded.

As to the arrangement of the articles, no special plan will be followed by the editor. Papers on topics closely connected, will be published in the same volume, but as a rule it will be the intention to have represented in each volume a variety of subjects.

By the creation of the committee on "Reviews of Ceramic Literature," the scope of the Transactions has been enlarged. It is the object of this committee to place before the members of the Society short reviews of prominent articles appearing in journals published in foreign languages, and titles of such articles, in journals printed in English. The work of this committee is bound to be valuable, if carried out properly, and though the beginning is small, it is hoped that the work will be more complete in the future, for the value of the work is in its completeness.

ALBERT VICTOR BLEININGER,
Editor.

Columbus, O., April 15th, 1905.

ADDRESS OF THE RETIRING PRESIDENT.

FRANCIS W. WALKER, Beaver Falls, Pa.

The informal gatherings of the members in attendance at the summer meeting of the Society were most enjoyable, and afforded an opportunity of discussing pottery to their heart's content.

The lovers of the "fictile art" have thus had an opportunity for the technical, as well as the artistic study of pottery and clay products, that can only be had through an exhibition such as the World's Fair, at St. Louis, has just afforded us. This magnificent exhibit of the world's finest products must have an effect on the pottery industry of this country.

That the interest in the technical study of Ceramics has increased, is evidenced by the increase in our membership and the attendance of the members at the meetings. Those who cannot be present to hear the papers read, and take part in their discussion, anxiously await the publication of the proceedings. The volume just issued is full of valuable information, and adds greatly to the literature of the Society. Many of our papers eminate from the graduates of the ceramic schools, who give to the society the benefit of the knowledge gained while students.

The effect these young men will have on the industry, as they become interested in the development of the practical side of their profession must be an elevating one. The papers read before our meetings show most careful thought in their preparation, so much so in many instances that discussion is withheld awaiting an opportunity for study and investigation, which frequently brings forth another paper upon the same subject.

It is only necessary to glance over the literature of the past few years, we might say, dating from the time of Dr. Seger's researches, and compare this period with all previous time, to see the rapid advancement in the technical knowledge of the ceramic industry. While the very able chemists connected with the Sevres factory published some

valuable information, it was not until the later period that the technical analysis of the clay industry became really beneficial to the practical clay worker. The establishing of ceramic departments in several of our universities has been the means of advancing the study of clays, and to the pioneer of this work, we must express our highest praise of his indefatigable efforts to build up and improve the methods, as well as the technique, of the clay industry. I refer to Professor Edward Orton, Jr., and the Department of Ceramics at the Ohio State University, at Columbus.

Professor Orton's study of clays, when connected with the geological department of the state of Ohio, under the direction of his eminent father, Dr. Orton, and his connection later with the brick industry, pointed out the necessity of greater technical knowledge to assist in working out the practical problems.

The difficulties he experienced in establishing the school were overcome by hard work, and today his department stands pre-eminently at the head, as far as the technical study, as well as the practical analysis of clays and silica products are concerned.

Some of the best papers read before the society have been by graduates of this school. The list of our most active members includes many of the young men, thus showing the broad and liberal principles instilled into them by their "Alma Mater," which led them to give to the world the benefit of their investigations.

Since the organization of the society, the New York State School of Clay Working and Ceramics, Alfred, New York, and the Department of Clay Working and Ceramics of Rutgers College, New Brunswick, N. J. have been established. To some of the members of the society, I feel perfectly safe in giving the credit of the inception and carrrying out of the hard work necessary to their establishment.

The New York school was established in 1900, and the Board of Managers gave evidence of their ability to create a school on broad and able lines in their selection of Professor Charles F. Binns to work out the plans of the

organization. Professor Binns was principal of the Technical School at Trenton at the time, which position he resigned to accept the honor connected with the establishment of the second school in this country for the study of ceramic science. As was to be expected by his friends, Professor Binns adopted an original line of work for which his broad experience in practical potting fully qualified him. In doing so, the technical study of clays has not been overlooked, as the requirements of the school are very exacting in chemistry, as well as in technology, and it has a department especially fitted for the examination and testing of clays. The technology of clay wares and the method of their manufacture, together with the artistic development of the potters' art has been made the principal study of the school, paying especial attention to lines of investigation in the problems of white ware and art pottery.

The first paper from a graduate of this school appears in volume six of our proceedings, treating in an able manner with the problem of "fine grinding," a subject that has been before our society several times, and should have some discussion at this meeting.

A description of the New Jersey school was given by Professor C. W. Parmelee in a paper at our Boston meeting. The school graduated its first class last year, and is in a flourishing condition. The effect upon the pottery industry of the state in bound to be very beneficial.

I have mentioned the ceramic schools with the object in view of leading up to the question: Do these schools receive the assistance and encouragement from the manufacturers of clay products they deserve?

If a truthful answer is given, I fear we must admit they do not; look around you, think over the clay factories known to you, and how many of them are employing one of these technical students? What encouragement is there for a young man to take up the study of clays if employment can not be found in his chosen profession? To quote from a letter received from the director of a large technical school, in which he says, "The average young man does not

realize the possibilities in the clay-working industries.' We might ask, does the average manufacturer realize the great possibilities? If he did, the man who has made technology his special study would be placed in the factory to assist the practical man in working out the problems which are causing constant losses.

An investigation will disclose in many instances that the practical potter is opposed to "theories," as he calls them, and will have nothing to do with them. Why, I might ask? For the very simple reason that he is afraid of himself, he fears his position, not realizing that his practical experience is fully as valuable, if not more so, in many instances, than the knowledge of the technologist. But when these two work hand in hand and assist each other to solve the problems, then, and only then, can our manufacture reach its destined place in the world's advancement

The manufacture of white ware, as well as of the heavier products of clay, such as brick, terra cotta, sewer pipe, etc., should and must in the future look to the technologist, if they expect to advance and keep pace with other lines of industry. There are, however, more technical men connected with the brick and kindred industries than with the potteries, and to this reason may be ascribed the higher standard of excellence of these products when compared with such products from other countries.

Assist the clay schools, help the young man to get technical positions, and thereby elevate an industry that has as great possibilities before it as had the steel industries twenty-five years ago, when the chemist was first associated in its development.

This assistance should also be given to the American Ceramic Society, not only by joining, but by attending the meetings. We need and want their assistance. They need the information that can only be had through the impetus given to investigation encouraged by such meetings.

Frequently the statement is made, "There are too many potteries." This may be true of the factories making the cheaper line of earthenware, but why not reach out for the top notch? Bring in the skill and knowledge of the

man capable of analyzing the difficult problems of body and glaze compositions; improve the quality of the ware, and the over-production will soon disappear. A very small reduction of the importation of earthenware will keep every pottery busy that has improved the quality of its ware.

Some matters from the practical side of the industry should have our attention. The method of firing kilns is a subject of interest to all; whether a down draft or an up draft is best for biscuit burning. Why one kind of kiln is preferable for certain wares but is not so good for other kinds. The subject of saggers is one of interest at all times, and an investigation that would lessen the loss to the potter would be of the utmost value to the society. A paper on the mining of crude materials, and method of placing on the market, and a suggestion of remedies for their irregularity, should be the means of procuring better materials. The miner of clay, in many instances, does not realize the necessity of a uniform product. The stripping may not be carefully removed, the clay may be too wet, a break in the vein may occur in which there are large quantities of iron, or a change in the grade may take place; but it is all sent to the potter. If he is fortunate and makes the discovery before using the material, a heavy loss may be avoided. Is it not possible to educate the producer to the point where our valuable clays can be relied upon for regularity?

The variation in foreign clays is very little. Is it because of better clays, or more care in mining? Possibly to some extent both; but proper care in mining will, no doubt, improve the quality of our domestic clays.

Mixing of the feldspars by the spar mills is a most dangerous practice, placing the potter at the mercy of an error by the laborer at the mill. A few suggestions upon this subject might remedy the variation in fusibility.

A committee was appointed at one of our earlier meetings to devise and recommend a standard method of testing clays. The committee was unable to make a report, and the matter was dropped. If a proper laboratory method of

testing clays would be established, it would be most valuable to the clay worker. It has occurred to me that this is a subject that could be placed before the United States Geological Department for working out. In the laboratory they have experts that could devote the necessary time to experimentation and investigation, and their results could be published in the reports of the survey.

Professional paper No. 11, by Dr. Heinrich Ries, recently issued by the United States Geological Survey, is a valuable report for practical use. The department should be encouraged to continue its investigations.

The geological department of New Jersey is to be commended for the able report, just issued, pertaining to the clays of that state, giving an exhaustive report of the deposits and complete analyses of the clays, together with the determination of physical properties, including shrinkage and absorption tests at various temperatures, making it the most valuable report, up to date, of any state geological department.

The geological departments of the various states could and would, if properly instructed as to the needs of the clay industries, work out and publish their reports on clays in a manner that would largely develop the clays of their states. Is it not within our province to make friendly suggestions to the state geologists in states having large clay deposits for reports that would be beneficial both to the state and the consumer of clays? Several states made excellent exhibits of their clays at the World's Fair, St. Louis. The state of Georgia showed some specimens of clay that should find a large sale, if the mines are of sufficient magnitude and the product is properly put upon the market. Texas made a large display of clays, but so poorly exhibited that it did not attract the attention the collection deserved. Missouri's crude clay exhibit was large, but not presented from a technical and practical standpoint to the extent the deposits of the state deserved. The able report of the geological survey on clays would have furnished data for working out the finest exhibit at the Fair. From a practical point of view, the clay exhibit of the state of

Pennsylvania was probably the most carefully prepared. The fine quality of the fire clays, as well as of the stone ware clays which were exhibited, was brought out by large blocks showing the crude clays, with similar large blocks in the burnt state, illustrating the change and shrinkage by comparison, and giving the temperatures, in cones, at which the blocks were fired, together with the analysis of each clay. From the technical view point the exhibit of the state of New Jersey was also made in a most able manner, giving the analysis and physical tests, and illustrated with fired samples for comparison.

Mr. S. Geijsbeek has prepared a complete report on the ceramics of the World's Fair which will appear in our proceedings, but I wish to mention a few of the exhibits that are especially worthy of the highest praise.

The exhibit of the "Royal Berlin" factory was the best in every respect, showing true hard porcelain in all shapes and decoration, the new soft porcelain, called Heinecke porcelain, in honor of their director, Dr. Heinecke, decorated under and over the glaze and between glaze layers, Seger porcelain in small vases, in ox-blood reds, crystalline glazes in zinc and titanic effects, and other magnificent wares.

The French Sevres exhibit was especially fine in crystalline glazes, mostly zinc effects. This exhibit was principally soft porcelain.

The exhibit of the Royal Copenhagen of under-glaze decoration on porcelain, developed at very high heats, is most remarkable for the beautiful soft effects. Their crystal glazes were very fine.

The Japanese show improvement in their technical skill, and their exhibit of the clay working school in the Educational building, showing ware modeled upon the most advanced principles, illustrating Seger's style of working, with their own thorough care in preparation, was an exhibit of the highest order from an educational point of view, and was in sharp contrast with the Chinese, who do not show any advancement over the ancient potter.

The technical porcelain exhibit of the Royal Berlin

and the chemical stoneware exhibit of Royal Doulton, are perfect illustrations of the mastery of ceramic technology.

The exhibits of some of our domestic manufacturers were very fine and worthy of the highest praise.

In this address I have endeavored to make a few suggestions as they occur to me, and trust they may result in some value to the society.

ADDRESS OF THE NEWLY ELECTED PRESIDENT.

Gentlemen:—I believe that not much is expected of me on taking the chair. There may be more required on leaving, because I shall hope to call attention to very many achievements accomplished by the society for the coming year. Some of the warmest friendships of my life have been made among members of this association. I cannot help but look back and draw lessons from the past. I cannot help but look back to that period in my life when I was new in the clayworking industry, something like twenty years ago, and note the difference in conditions at the present time from those that existed then. Back of that, for all time in the history of the clayworking industry, we all know that the utmost secrecy obtained. Men had been reaching out in the dark and trying experiment after experiment, until someone by chance would be led to a receipt, which he would treasure and which would be handed down from father to son with the utmost secrecy. While some would discover these receipts, others failed, and this led to a system of spying out. In some cases, men have feigned idiocy, and thus broken into other establishments, where they would take cuffs and kicks, in order that they might have opportunity for spying out the secrets of those establishments.

But now, one does not have to feign idiocy in order to get a start in the ceramic industry. So short a time as twenty years ago, there was really no good literature obtainable in America on the clay industry. I remember about the first thing I got hold of in a literary way was a drainage journal. This growth has come about almost entirely from a little association of earnest technical men getting together for earnest talks, promoting the growth of a helpful feeling among them. This little association of tile manufacturers got together, and a trade journal was started, followed by other trade journals. Finally the National Brick Manufacturers Association was organized,

and it has been in the field nearly twenty years. I hold that if the N. B. M. A. had accomplished nothing else than to have led to the organization of this society, it would have been abundantly repaid for all its labors. But no one can measure the good done by that association—the numerous failures averted by one manufacturer enlightening another, thus saving him from errors already made by the informant. Much of this has occurred outside of the meetings, and is unrecorded. The friendly feeling which one manufacturer has for another has been demonstrated from time to time. Then when Professor Orton was ready to start his school, this organization came to the front and helped to hold up his hands. It provided for a scholarship in that school for the good of the cause. I doubt whether this society would ever have been in existence but for the N. B. M. A., and we shall certainly always feel kindly toward them for what they have done for us.

Then in the publications of this society, I believe there has been furnished more of good, meaty literature for the clayworker than anywhere in the English language. It has certainly been wonderful to note how men, busy as they are, have come forward here in our meetings and given the fruits of their research and their time. We all appreciate the work of Seger being put within our reach. According to all traditions, those members who were familiar with Seger in the German should have sat down on it and locked the doors. But they did not do this; they gave freely of their time and talents and translated it, in order that the English speaking people of the world might have it unlocked to them and thus made accessible. To me, this broadening change in fellowship, the helping of one man by another, is evidence of the value of this association, and the redemption of human nature.

I have always felt that I have been delinquent in the matter of contributing information here, though I have received much from members; but I have always fallen back on the thought that I was not able to help those who helped me. I could only pass on this help to others less

experienced than myself. That has been essentially the spirit of this organization.

In looking over the last number of our proceedings, a good many things impressed me strongly. There are a good many things we are still reaching out for, things which are unfinished from one meeting to another. Many will be unfinished for many years, and may be forever. The question of plasticity of clay was transferred to a committee, and we have been studying on it ever since. I hope to see much done on that line. To me it is a question of vital moment, a most interesting question. What is that plasticity which we can only judge by feeling? We may construct elaborate machines for testing plasticity and, after all the details have been classified, we say "That is the result, but I do not know what it proves, after all."

Last year we had much that was interesting to me, and I want to call your attention to one or two things that impressed me. There was much regarding the relationship of these microscopic particles, one to another, and I think there is much yet to be determined by the microscope as to the shape and condition of these particles, and its bearing on making the clay plastic. The one real test of clay is its plasticity, though it is hard to explain. It seems to me that much depends on the shape of these particles, whether rectangular or round, whether touching each other only at points or interlocking. I think Professor Wheeler advocated the theory of planes lapping over one another, the moisture tending to hold them together, as boys used to do with leather suckers so they would be hard to pull apart, but would slide readily over one another. We had Dr. Cushman's theory that these particles are spongy, and greedily drink up any liquids thrown in. I consider this theory an important addition to our point of view.

We have had another question before us which is interesting to me, viz., that of crystalline glazes. As you know, Mr. Stull talked on that subject at our last meeting, and later wrote a paper on it. I do not want to say it boastingly, but I want to call attention to the fact that Mr. Stull's work was the direct outcome of scientific work

in our laboratory, based on the training of Professor Orton's school. We deliberately attacked the problem of making these crystals, and after our experimenting, reached the results shown in Mr. Stull's paper. At the World's Fair at St. Louis, the Copenhagen works showed pieces of the same thing, or right in the same line, though not knowing that anything was being done on this side of the ocean. They worked out the same problem. In the French Pavillion were beautiful specimens of crystalline ware, worked out by the Sevres Porcelain Works in France. I am proud of the fact that here in America, this problem has been worked out by a private institution, unaided by the government; and I believe that what we have done so far, is just the beginning. On the train, Mr. Hottinger showed me something in crystal ware that he had done, which is admirable.

I have said that we should be broad-minded and help each other, and I wish to show that my words are more than mere air. I have a package here which will interest you in this connection. (Shows sagger bottom covered with large patches of magnificent crystals of the glaze described by Mr. Stull, Vol. VI, p. 185). As Mr. Stull's article failed to state clearly just what the crystal glaze is, I will write down on the blackboard, the batch weights of which it is composed, not the formula, but the batch weights, just as used in making it. I hope some of you will experiment during the coming summer, and that next year we shall have a set of still more interesting results.

The formula of the glaze on the sagger bottom is:

	Per Cent.
Potassium nitrate	24.91
Zinc oxide	23.30
Flint	41.92
Rutile	9.87

This is fritted at about cone seven, preferably running into water; then the frit is ground finely and applied to the ware simply with dextrine. The ware should be burned to about cone six. The manipulation and firing is a very delicate operation. I have in my baggage a little

Bottom of a Sagger, in which the crystalline glaze described by Stull had been fired. The glaze in this case had slipped off from pieces of ware in the early stages of firing, and afterwards fused and flowed over sagger bottom, on the surface of the original soft glaze which covered the latter.

vase of the same character, showing that if the firing is not exactly right, there will be no crystals at all. If the firing is carried too far, you will simply have a plain glaze without any tendency to crystallization.

This sagger had been given a soft lead glaze, and it shows where the crystalline glaze has mixed with it, and here (indicating) is a thick enough body of the crystalline glaze to wholly obliterate the other. In the fractures of the crystalline glaze, it shows a crystalline structure running through the entire mass. The tendency of the crystals to absorb coloring matter is also characteristic. In many cases where the crystalline glaze was used, all the color has been collected in the crystals, and those parts not covered by the crystalline glaze are devoid of the coloring stain.

I will add that I think it is important, after arriving at the proper temperature, to hold it a little while. But if the heat is carried further, there is no trace of crystallization in such cases, excepting at the bottom of the vase. We had better results in firing this ware in small kilns. We held it there, after attaining the proper heat, for six or eight hours; possibly a little longer. I think the main thing is to get just the right degree of heat. We cool fairly slowly. I think after the heat drops a little it can be cooled down more rapidly.

I want to say that I want any of you to feel free to write me in this matter at any time, and I will render all the assistance I can. Mr. Hottinger, have you your piece here?

Mr. Hottinger: No; but I can get it. (Leaves room for sample).

Mr. Gates: Mr. Hottinger has prepared a piece which is an interesting study to me, showing broad star shaped blue crystals, arranged in large stellate groups. I was more than pleased to see that Mr. Hottinger, working by himself, had obtained such fine results as these crystals, which he tells me are colored blue by nickel. It is wonderful that both of us, working separately and as competitors, should have come here with a discovery so closely related.

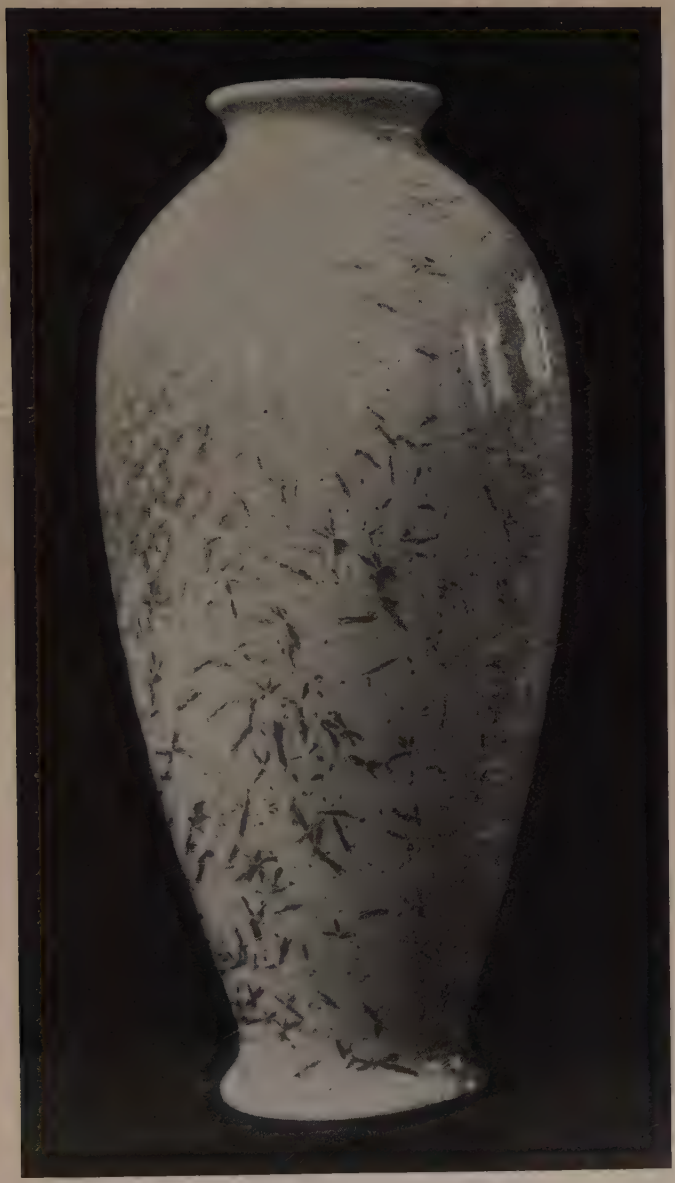
I do not want to take too much time, but I have tried to give you a practical sign that I mean what I say when I make the statement that I am willing to give up something for the advancement of science.

I have taken up more time here than I intended. I hope you will bear with me, and I will try to perform the duties of this office to the best of my ability. I thank you for bestowing this high office upon me, for I know that I am not worthy; but I will do the best I can and ask for your forbearance.

DISCUSSION.

Mr. Watts: (Exhibiting specimen). We have here a case of crystalline structure which came to my attention. This was originally made for a dark brown, almost a Rockingham brown. Owing to the choking of a small section of the kiln probably a dozen pieces of this kind were obtained. Several micro-photographs were made of this glaze, one a low power and two high power photographs of 614 diameters. The first was made with ordinary light thrown up from below and the other with polarized light.

Note:—The specimen exhibited by Mr. Watts was a section of an electric insulator, showing, in the brown glaze, surface crystallization consisting of gold-brown crystals, grouped concentrically around a center of crystallization.



Crystalline Glaze, exhibited by A. F. Hottinger. The crystals are $\frac{1}{16}$ to $\frac{1}{8}$ inch in width in the narrow dimension, and $\frac{3}{8}$ to $\frac{1}{2}$ inch long. The stellate groups are $\frac{3}{4}$ inch in diameter. The crystals were said to be zinc silicates, colored to a delicate blue by nickel oxide. The body of the vase is cream or fawn color.

LESSONS FROM THE ST. LOUIS EXPOSITION, 1904.

BY

CHARLES F. BINNS, Alfred, N. Y.

The recurrence of international exhibitions affords an important opportunity for studying not only the progress of the nations in industry and art, but their relative positions and comparative growth.

The fair recently held at St. Louis may be made useful in this regard, and to American ceramists the occasion is one of importance.

Two things are commonly sought by one who is interested, novelty of idea and quality of execution. But in what does novelty exist? Given the necessary materials and conditions, what new arrangement or combination is possible? Body, glaze and color are, like the poor, always with us, and the methods of formation, burning and decoration are essentially constant.

Quality may be found in two directions, one mechanical, the second artistic. In the former, the application of the skill of the hand, or the more perfect action of a machine may be considered; in the latter, where the subtle influence of art comes into being, the whole question becomes one of individual perception, for in art one man is blind while his neighbor sees.

In passing through the buildings at St. Louis one was confronted by a strange contradiction, which seemed to arise from a colossal mistake. I allude to the division of the exhibits of pottery into two parts, one being placed under Manufacturers and the other under Mines and Metallurgy. The result of this was, that exhibitors of clay wares found themselves under different groups, and their products were examined by different juries. On the face of it, there seems to be no reason why the manufacture of pottery

should be severed from the manufacture of other goods, and there is no more reason for placing pottery under Mines and Metallurgy than there would have been in exhibiting gentlemen's clothing in the building set apart for agriculture. However, we learn by our mistakes, and there does not seem to be the slightest doubt that this error will never be repeated.

It was scarcely to be expected that there would be large exhibits of heavy clay wares from abroad, but the domestic producers were well up-to-date in the manufacture of fire-proofing, terra cotta and refractory goods. As a building material, clay is pushing rapidly ahead, and the recent improvements in hollow blocks for walls and floors will still further promote its use. The curved block for grain elevators and silos is one of the newest developments.

In terra cotta we have no competitors, but must perforce fight each other. The only point I would like to make here is to enter a plea for broader and less ornate work at the tops of high buildings. The mass of detail is absolutely unintelligible to a passer-by, while the same or a smaller cost would have sufficed to execute models upon broad, strong lines, which would not only be an artistic revelation but an educational factor of importance.

In refractory goods much progress has been made. The use of bauxite and an intelligent study of the function of grog have brought our fire-brick, glass pots and gas retorts to a condition of high quality.

There is a strange reluctance on the part of American manufacturers of table wares, to take part in an exhibition. The Germans, the French, the Belgians, the Danes, the English, the Japanese, the Swedes, were well represented, but not the Americans. It must cost these foreigners infinitely more, proportionately, to make their displays than it would cost an American, and yet we allow ourselves to be outclassed and almost snowed under. I have given much thought to this matter, striving to find the reason and to read the lesson. There are said to be three factors in the case:

1. Money. An American will not, as a rule, spend money unless he can see a probable return which can be traced directly to the expenditure. In many cases he does not deal with the public at all, and has no interest in showing them his goods.

2. Business. Preparation for an exhibition takes time and attention. It disorganizes the factory and upsets the routine.

3. Competition. Most of our manufacturers shrink from the direct comparison of their wares with those of Europe.

I would like to take a moment to reply to each of these points.

The policy first mentioned would seem to be short-sighted, and it is doubtful whether it be sincere. We are not averse to spending money for advertising, and the publicity thus sought and secured is parallel to that to be obtained in an exhibition. The patronage of the public is most certainly to be desired, and if it will pay the makers of a certain cracker or a special coffee to create a demand for the article to which a name and reputation may attach, it will surely pay to achieve similar results in pottery. But, alas, we are confronted with the fact that only a very few makes of ware have any distinctive merit—please note that I say, not "merit," but "distinctive merit." There is, without question, merit in the characteristic American wares, but it is well known that a stock order might be filled by twenty manufacturers and no one could tell the difference.

The remedy is, that potters shall dare to be original, and then they will be glad that their product shall be known.

Under the second head I would remark that no success is to be attained without trouble. On the occasion of a great exhibition it is to be expected that unusual efforts will be put forth. If the foreigners can produce special designs for an occasion, we surely can, but yet, while in the presence of a full order-book, exhibition goods must be made for the purpose of the exhibit, it is all the better if

they can be made of the class and style regularly manufactured. To employ for the time being a celebrated modeler and an experienced painter, discharging them when the exhibition work is ready, is not fair either to the manufactory or the public. The regular staff is disheartened by the thought that they were not considered good enough for special work, the public is deceived into thinking that this work represents the normal standard of the factory.

In the third place it has been suggested that our manufacturers fear to place their goods in direct competition with those of Europe. The idea of this is so contrary to American enterprise and pluck, that it cannot be accepted off-hand. But is there any truth in it? There is, in this sense. We produce wares of a different type from the European, and it would be manifestly unfair to place hotel china in comparison with French porcelain; they are not in the same class. Our manufacturers are, therefore, not to be blamed when they decline to set a confusing condition before a non-discriminating public. I do not speak here of the risk of puzzling the juries, because they are supposed to know. This reason, however, should not be allowed to rule, and it is most earnestly hoped that we will soon be able, without fear, to meet the European manufacturers on their own ground.

The comparison between European and American wares only favors the foreigners when the finer elements of art and delicate handling are to the fore. In every instance where the intelligent use of mechanical power, or the management of intricate machinery is the important factor, we lead the world.

In the production of ornamental and artistic wares the nations enter into close competition, but America only shares that portion of the field occupied by faience, in porcelain we are unknown. Crystalline glazes are now so generally produced, that it is only in the minuter variations that a comparison can be made. Berlin has a delightful crystal of copper color, and Japan, a curious titano-manganic crystal which is unique. The more usual type of zinc crystals has been brought to great perfection by

both Copenhagen and Rorstrand, while the Royal Manufactory of Sevres exhibits large pieces of the same character. This fact is useful, if only to demonstrate that crystalline effects belong to the jewelry rather than to the architecture of ceramics.

Among the distinctive porcelains which owe their quality to science rather than to art may be placed the Copenhagen reticulated or speckled glaze, of which an occasional piece has been produced in the last few years. Though I have credited this work to science it must be granted that art, both in the sense of discriminating taste and skillful handling, has a large share in it. The effect is evidently the result of a glaze which freely breaks up on drying, but of which the tiny separated beads do not fall off, and I imagine that the rarity of the work is caused by the extreme difficulty of holding these detached fragments on to the ware until the fire shall secure them. The pieces are usually glazed in reticulated white over green, blue or ivory.

In underglaze porcelain painting there is one new achievement only, the so-called plastic painting of Berlin. The porcelain is a modification of Seger's demi-grand-feu ware, and is closely allied to the porcelaine nouvelle of Sevres. The painting, mainly of fruits, is executed in brilliant colors, and is the most notable success of its kind in recent years. Work in this direction has formerly been of the subdued character best exemplified at Copenhagen, and at the high porcelain fire. The Berlin ceramists have succeeded in securing a brilliant porcelain at a fire which renders a rich palette of colors possible, and the result illustrates the fact that our want of success in underglaze work has been due less to the glost kiln heat than to the nature of the glaze employed. The colors are far superior to the ordinary run of underglaze colors, and they have been handled with masterly skill. They appear to have been used beneath the glaze and not over the finished porcelain in a second glaze fire, as is the habit of the French.

Closely allied to porcelain is the hard-fired stoneware generally known as gres. Of this ware there was only one

exhibit of marked importance, that of Paul Jeanneney, of St. Amand. The superb modeling, the beautiful texture, and the strong subdued tones combined to make this exhibit one of the triumphs of the Fair, albeit somewhat neglected by the general public. With the wealth of stoneware clays in this country, there is a hopeful prospect of the production of gres being taken up by American potters.

In the field of Faience the whole world competes. Matt glazes, flambe glazes, rich colors and quiet tones, modeling, glaze painting and texture effects are all abundantly represented.

The brilliant hues are found mainly in Europe, where Zsolnay, of Hungary, takes the lead, though some of the flambes of Robertson, of Dedham, exhibited in the Art Gallery, present novel and equally radiant effects. In the matt glazes of Ipsens, Scharvogel, Van Briggle, Grueby and Teco wares there is nothing specially new, though interesting and pleasing combinations abound. The work covered ground which is now familiar to practical ceramists, but the one development which is daring in its conception, and perfect alike in its application and treatment, is the vellum glaze produced by Rookwood. According to rule, and as borne out hitherto by experience, a matt glaze is opaque in its very nature. But genius disregards rule and becomes unto itself a law. Underglaze painting we know, and matt texture we know, but this is both. The painting, executed in the most perfect style of the Rookwood studios, has been tenderly veiled by a glaze of such a nature, that while the delicate texture of the matt is unimpaired, the colors beneath are allowed to retain their quality. This work has been pronounced by a well-known authority to be the most distinct ceramic novelty of the century, and in the verdict all who understand and love their art must fully concur.

The potters of England stand in a class by themselves. The beauties of English china admitting an exceptionally fine character of over-glaze painting, and the excellent quality of the English earthenware, command respect for the skill of the potters and admiration for the result

of their labors. Two novelties must be noticed. The copper red of Doulton and the colored glaze work of the Ruskin pottery by Mr. W. Howson Taylor. In the former case it is evident that too much has been claimed. A special pamphlet blazons forth the rediscovery of a lost art, whereas it is plain that the red is a low fire enamel over a porcelain glaze. The colors are indescribably rich, but the ware is not a rediscovery of Chinese copper red, nor has the art of this production ever been lost.

The Ruskin pottery deserves great credit for the refined taste and artistic restraint with which their wares have been put forth. The glazes are brilliant in surface, the colors are admirably chosen, and the forms well designed. The ware is an illustration of the possibilities which lie in the daily operations of the potter. As a French chef can evolve new dishes and subtile flavors from the ordinary contents of the pantry, so the skilled and enthusiastic potter needs not the discovery of new materials or processes, but from the treasury of a resourceful mind can bring new things out of the old, even though there be nothing new under the sun.

This is the lesson of St. Louis. Our art is infinite. We have clay, glaze, color and fire. With these the creative mind can express itself, and only the feeble and effete will find an excuse for stagnation or for misdirected energy, in the complaint that it has all been done before.

DISCUSSION OF "LESSONS FROM THE ST. LOUIS WORLD'S EXPOSITION."

Mr. H. A. Wheeler: A few comments might be made on Prof. Binn's interesting paper. His criticisms are very gratifying to those of us who were fortunate enough to see the ceramic triumphs, as well as those that were not, but which were, nevertheless, highly instructive and interesting. There is a matter that is, perhaps, not clear to him. Some three years ago when the National Brick Manufacturer's Association went to the director of exhibits to see that the clay industries should be given proper recognition at the St. Louis Exposition, the director, on going

over the classification, said, "Gentlemen, clay products can be exhibited in seven different buildings, but if you want to try to bring them together and make one complete, collective clay industry exhibit, the only one building in which this can be done is the Mines and Metallurgy building." It was therefore attempted to bring together the raw material, processes and finished products in the Mining building, on the supposition that to understand finished products one must see raw materials, and in order to appreciate the value of the raw material, one must see the finished product. At St. Louis, as at pervious exhibitions, clay products were exhibited in the Fine Arts, in the Varied Industries, Manufacturers', Liberal Arts, Machinery, Horticulture, Agricultural and Mines and Metallurgy buildings. The result was, that unless the ceramic student had either a very large amount of time or the benefit of an exceptionally well posted guide, many ceramic exhibits were never found, as the exposition covered the enormous, unprecedented area of 1,260 acres.

One of our leading ceramists who visited the exposition had hard work to cover this field in three weeks, yet he devoted nearly all his time to this one subject and had the best of local guides. The National Brickmakers Association, therefore, showed a broad-gauged, progressive spirit in trying to avoid the weakness of previous expositions when they attempted to bring together, in one complete exhibit, the clay industry of this country. It was no choice on their part that the Mines and Metallurgy building was selected for this exhibit. The actual exhibit made in this building, under their inspiration, did cover the entire field of ceramics, or from the highest to the coarsest wares, and from the raw clays through the processes to finished products. It is true that it was not a well balanced collection, as some departments were better represented than others, while one was lamentably weak. Prof. Binns' criticism of the most disgraceful lack of American exhibits in what is popularly known as white ware or china ware, is only too true. There was one bright exception, however, of which, I am sorry, Prof. Binns did

not make mention, or the exhibit of bone china by the Onondaga Pottery, which was quite the equal of the best European ware.

The classification of the exhibits by the exposition had been issued previous to the efforts of the N. B. M. A. to concentrate the clay industry in one building, and it was impossible to modify it, so that exhibitors who wished to enter ceramic goods in any of the seven buildings previously mentioned were at liberty to do so. The effort was made, however, to persuade exhibitors in behalf of their own interest, as well as in justice to the public, to concentrate all the American ceramic exhibits in one place, notwithstanding the official classification, and with quite successful results.

While the resulting clay industry exhibit in the Mining building was not perfect, it proved highly beneficial to the exhibitors, and was greatly appreciated by the public. It was an important and successful innovation which we hope will be followed in future expositions, and be carried out more effectively than in this pioneer effort.

We accomplished one thing, as I was largely responsible for carrying out the complete industry idea, which certainly is of the highest value to the ceramists in this country. It made such a strong impression and accomplished so much good, that the clay industry exhibit in the Mining building, with minor exceptions, has been secured for permanent installation in the new national museum in Washington. This should certainly interest this society, as it is the first recognition by our government of the importance of the ceramic industry. In justice to the joint efforts of the Louisiana Purchase Exposition and the National Brick Manufacturer's Association, this society should know why the great majority of American clay exhibits were successfully concentrated on that half acre in the Mines and Metallurgy building.

SOME EVIDENCES THAT BODIES HIGH IN SILICA CRAZE BY OVER-FIRE.

BY

CHARLES WEELANS, Trenton, N. J.

In presenting to the society work designed to instruct and advance the knowledge of ceramics, it is probably necessary that it be more or less scientific in character, and such being the case, only the purest materials obtainable should be used, in order that the results may be comparatively easily verified, and positive.

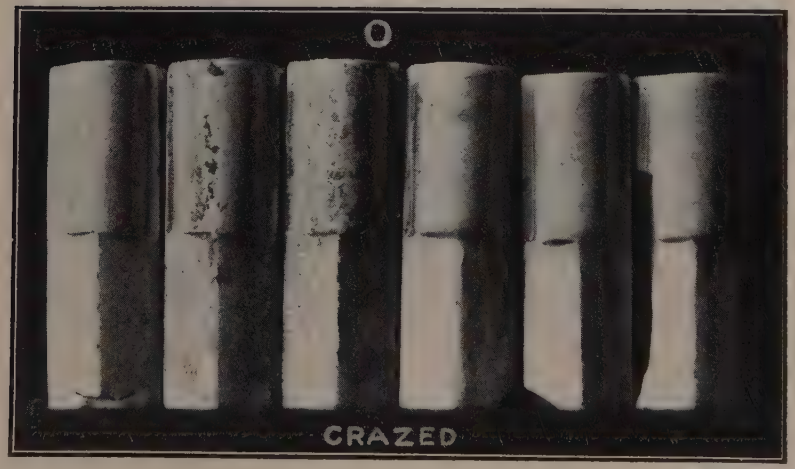
This is consistent, I believe, with the object of this society, and probably in no other manner could it hope to be of enduring value, or extend its usefulness.

It is probable, however, that inasmuch as scientific knowledge can be of benefit only when applied, and that in its application practical experiments are necessary to fit it to the many and varied conditions met with in ceramic manufacture, it would not be out of place, when opportunity offers, to discuss the subject from a practical standpoint, offering as evidence, samples of work wherever possible.

It is with this idea in view that the work upon this note here given was undertaken.

In practical work we use the best materials possible, but while they may be good commercially, they are not pure in the strictest sense, nor constant in composition. This fact explains to some extent, that in applying technical knowledge to practical work, varied, uncertain, and many times unsatisfactory results are obtained.

Likewise, the sizes and style of kiln, long or short fire, quick or slow cooling, are very important factors in the work of the potter. It is these points of the manufacture that upset many pet theories, so beautifully worked out and designed, and expected to be of so much value and assistance. Bodies and glazes, when fired in small experimental kilns, are often entirely different when taken from



Series 0. All are crazed. The crazing increases from left to right. Discolorations on numbers 2 and 3 are from attempt to use ink in making craze marks more apparent. Partially successful in lower left part of No. 2.

the large kilns used in practical work; the same may be said of experiments made in small pieces and in small quantities; even when repeated many times, they often fail to give positive results. In regard to this, every experienced potter can give eloquent testimony.

A review of these facts, therefore, seems to offer to me sufficient encouragement to warrant the writing of experiences, based on the practical standpoint and carried on under everyday conditions, experiments made with such materials as are commercially satisfactory, and which are used by manufacturers generally.

With these thoughts in view I have carried out a few experiments intended to give some evidence in regard to bodies, high in silica, which craze by over-fire, and as shivering is one of the family of potters' troubles, to submit a few trials showing the defect of shivering, and some of its causes.

It will be noticed that these points are not new, as they have been taken up and explained with great ability by Seger, Burt, and others.

Series 0. (See table, page 59).

These trial pieces were made from a plaster mould, six and one-half inches in length, one half rounded and the other half with sharp points, the object being to secure, as nearly as possible, the conditions which are met with in various styles of pottery ware, with reference to round places and sharp edges.

This series was fired in the biscuit between cones fourteen and fifteen, being covered with flint in a sagger. The glost burn was carried on at cone ten.

As will be seen, the compositions run from 24% of flint to 35%, and from 32% of spar in No. 1 to 16 in No. 6.

The first three of this series crazed badly, and also the remaining numbers crazed until the content of flint reached 25%, in No. 6. It was the writer's intention, originally, to endeavor to overcome the crazing in these high fired pieces by changing the glaze, as had been done

many times in practice, but time would not permit this.

I will say, however, that we, very frequently, found in our high fired body a number of pieces which were over-fired, and while not always successful in saving them in the glost by adding flint and ground, fired body, to the glaze, we found it sufficiently successful to warrant our doing so.

This point is well brought out in Burt's paper, Volume V., of our transactions, and explained as follows:

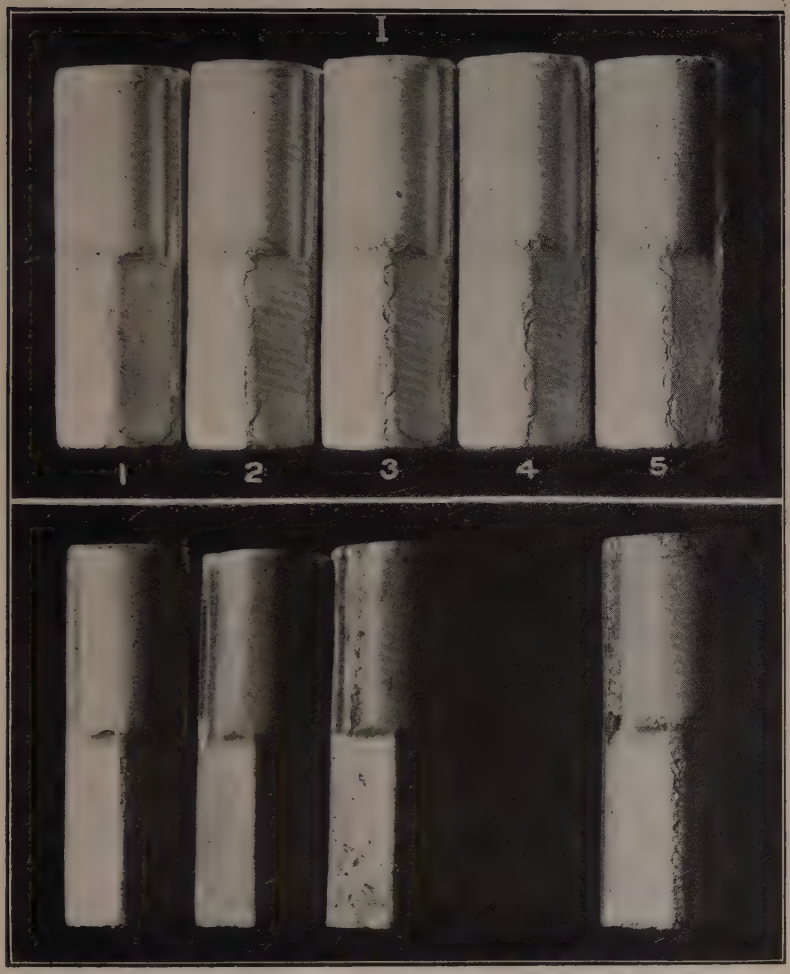
"A vitrified body, made so by over-fired biscuit, crazes through glaze not being able to take up flint from the body, which is in a state of combination and no longer crystalline. To prevent this over-fired biscuit crazing, put into the glaze all the flint it will carry to make up for the above deficiency."

The crazing of glazes is due to so many causes, direct and indirect, that one is compelled to wonder that Seger was so successful in classifying them, and in furnishing remedies. There are many practical men, however, who refuse to accept all the theories advanced by Seger or his remedies, their experience apparently having been contradictory. In this regard the writer has had some experience, which, if not properly interpreted, might appear in direct conflict with Seger's laws.

One instance in particular I will mention as an illustration. I was using some experimental pieces with a glaze which came from the kiln bright and smooth, but invariably crazed; sometimes as the trials came from the kiln, sometimes a few days later.

I was much puzzled to know the cause. In Seger, volume 2, page 609, under the head of removing crazing from a given glaze, we find given this law: "Decrease the clay substance and simultaneously increase the quartz content." I reversed the above rule, and crazing disappeared entirely.

This seems to be a complete contradiction, but when I explain that my increase of clay substance was small and my decrease of flint was greater, and that my trouble was



Series 1. Upper Series fired to Cone 10. Lower Series to Cone 14. All shivered at lower temperature. 2, 3 and 4 crazed at higher temperature, while others still shivered.

Glaze Formula.

$$\left.\begin{array}{l}0.117\ ZnO\\0.313\ K_2O\\0.570\ CaO\end{array}\right\}0.43\ Al_2O_3\ \Big\}\ 2.98\ SiO_2$$

Feldspar=K_2O, Al_2O_3, 6 SiO_2—combining weight=557
Cornwall stone=K_2O, 2.5 Al_2O_3, 20 SiO_2—combining weight=1550
Kaolin=Al_2O_3, 2 SiO_2, 2 H_2O—combining weight= 258
Flint=SiO_2—combining weight= 60

Series	No.	Florida Kaolin Per Cent.	English Kaolin Per Cent.	Flint Per Cent.	Feldspar Per Cent.	Body Formula	Shrinkage: Green Length	Shrinkage: Length of burnt trials	Shrinkage: Per Cent. Shrinkage	Results
0	1	20	24	24	32	0.2520 K_2O, Al_2O_3, 4.76 SiO_2	6.50	5.75	11.50	
	2	23	27	27	23	0.1758 K_2O, Al_2O_3, 4.62 SiO_2	6.50	5.80	10.70	Crazing tends
	3	25	29	29	17	0.1270 K_2O, Al_2O_3, 4.52 SiO_2	6.50	5.75	11.50	to increase with
	4	25	29	30	16	0.1206 K_2O, Al_2O_3, 4.58 SiO_2	6.50	5.50	15.30	each higher
	5	25	26	33	16	0.1270 K_2O, Al_2O_3, 4.95 SiO_2	6.50	5.45	16.10	number.
	6	25	24	35	16	0.1290 K_2O, Al_2O_3, 5.19 SiO_2	6.50	5.40	16.90	
I	1	35	15	40	10	0.0845 K_2O, Al_2O_3, 5.49 SiO_2	6.50	5.75	11.50	Shivered.
	2	30	15	45	10	0.0930 K_2O, Al_2O_3, 6.27 SiO_2	6.50	5.84	10.10	Shivered. Crazed in harder fire.
	3	25	15	50	10	0.1035 K_2O, Al_2O_3, 7.23 SiO_2	6.50	5.89	9.30	Shivered. Crazed in harder fire.
	4	20	15	55	10	0.1165 K_2O, Al_2O_3, 8.43 SiO_2	6.50	5.94	8.61	Shivered.
	5	15	15	60	10	0.1333 K_2O, Al_2O_3, 9.98 SiO_2	6.50	5.84	8.61	Shivered.
					Cornish Stone					
II	2	15	35	40	10	0.0341 K_2O,Al_2O_3, 6.44 SiO_2	6.50	5.94	8.61	In this series the spar is replaced by Cornish stone. The series shivered worse than I. Nos. 1 and 2 when burnt harder, stood.
	1	15	30	45	10	0.0309 K_2O,Al_2O_3, 5.64 SiO_2	6.50	5.84	8.61	
	3	15	25	50	10	0.0379 K_2O,Al_2O_3, 7.43 SiO_2	6.50	6.03	7.23	
	4	15	20	55	10	0.0428 K_2O,Al_2O_3, 8.67 SiO_2	6.50	6.03	7.23	
	5	15	15	60	10	0.0490 K_2O,Al_2O_3,10.27 SiO_2	6.50	6.08	6.46	

not the glaze but my inadequate fire, it is no contradiction at all. I was merely firing too low, and had I observed his rule 1, given on the same page, I need not have changed the glaze at all.

Therefore, to prevent crazing in the glaze by increasing the silica, depends much upon the condition causing the trouble. If the ware is over-fired, as is the case with the trials here submitted, or where the fluxes are too high, an increase of silica will very likely prevent it, but if crazing is caused by a content of silica, already too high for the fire used, though the glaze be bright, as were my experimental pieces, the silica must be lowered or a higher fire must be used.

Series I.

Peeling is characteristic of all tests in this series, increasing as the silica increases.

Series II.

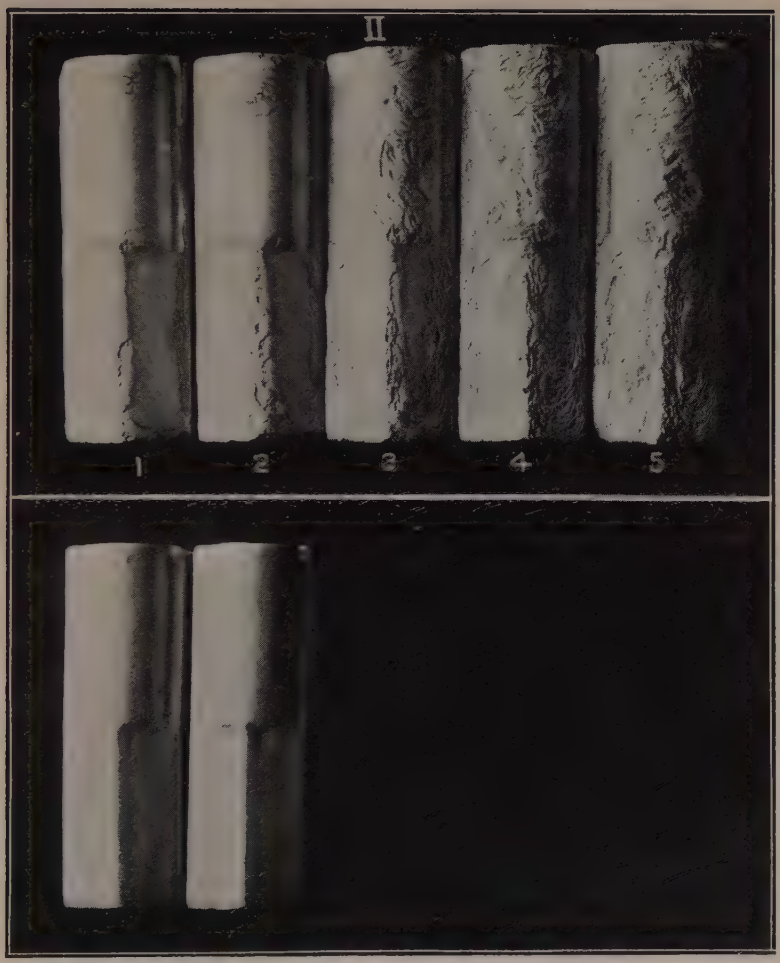
Each one of this series is also peeled, but much more so than the corresponding numbers in Series I, which fact is evidently due to increasing the English china clay at the expense of the Florida clay, and assisted by the substitution of stone for spar.

Series III.

Number 1 of this series differs from No. 3, series I, only in the percentage of the two clays used. This number is peeled. In No. 2 of this same series we decrease the silica content by 5% and increase the spar by 5%, the percentage of clays remaining the same, which change takes it from peeling to standing. The remaining numbers, by increase of the spar at the expense of the flint, continue in hardness until a good vitrified body is reached.

Series IV. (See table, page 61).

In this series we increase the Florida clay at the expense of flint, No. 1 being as high as 55% in flint. Yet an increase of 5% spar over series I, No. 1, which peeled badly, takes it from peeling to standing. At the end of the series it will be noticed that we have a clay content of 70%, none of the numbers showing signs of crazing.



Series 2. Upper Series fired at Cone 10. Lower at Cone 14. All shivered at Cone 10, growing progressively worse with increase of stone. Nos. 1 and 2, at Cone 14, stood.

Series	No.	Florida Kaolin Per Cent.	English Kaolin Per Cent.	Flint Per Cent.	Feldspar Per Cent.	Body Formula	Shrinkage			Results
							Green Length	Length of burnt trials	Per Cent. Shrinkage	
III	1	20	20	50	10	0.1035 K_2O, Al_2O_3, 7.23 SiO_2	6.5	5.89	9.30	Shivered
	2	20	20	45	15	0.1479 K_2O, Al_2O_3, 6.71 SiO_2	6.5	5.75	11.50	Stood
	3	20	20	40	20	0.1881 K_2O, Al_2O_3, 6.24 SiO_2	6.5	5.94	8.61	Stood
	4	..	..	..	..	0.2246 K_2O, Al_2O_3, 5.82 SiO_2	6.5	....	.....	Stood
	5	20	20	30	30	0.2596 K_2O, Al_2O_3, 5.43 SiO_2	6.5	5.45	16.10	Stood
	6	20	20	25	35	0.2883 K_2O, Al_2O_3, 5.07 SiO_2	6.5	5.41	16.70	Stood
	7	20	20	15	45	0.3426 K_2O, Al_2O_3, 4.43 SiO_2	6.5	5.45	16.10	Stood
IV	1	20	10	55	15	0.1878 K_2O, Al_2O_3, 9.15 SiO_2	6.5	5.84	10.10	Stood
	2	30	10	45	15	0.1479 K_2O, Al_2O_3, 6.71 SiO_2	6.5	5.84	10.10	Stood
	3	40	10	35	15	0.1218 K_2O, Al_2O_3, 5.13 SiO_2	6.5	5.55	14.60	Stood
	4	50	10	25	15	0.1037 K_2O, Al_2O_3, 4.02 SiO_2	6.5	5.41	16.70	Stood
	5	60	10	15	15	0.0902 K_2O, Al_2O_3, 4.02 SiO_2	6.5	5.50	18.20	Stood
V	1	20	10	60	10	0.1340 K_2O, Al_2O_3, 9.98 SiO_2	6.5	5.97	8.15	Shivered
	2	25	10	50	15	0.1654 K_2O, Al_2O_3, 7.79 SiO_2	6.5	5.75	11.55	Stood
	3	30	10	35	25	0.2246 K_2O, Al_2O_3, 5.82 SiO_2	6.5	5.41	16.70	Stood
	4	35	10	25	30	0.2358 K_2O, Al_2O_3, 4.77 SiO_2	6.5	5.47	15.80	Stood
	5	40	10	10	40	0.2698 K_2O, Al_2O_3, 3.71 SiO_2	6.5	5.97	8.15	Stood. Started crazing in hard fire.

Cracking of the body as the clay content is increased is the chief characteristic of the series.

Series V.

We start out with 60% of silica and 10% spar, which peels badly. In No. 2 we reduced the silica 10% and increased the spar 5%, which stops the peeling, although we have 50% of silica while No. 1, series No. I, with but 40% silica and but 10% of spar, peeled badly.

All the numbers that peeled at a medium heat show improvement when the heat is increased, but in none does peeling entirely disappear.

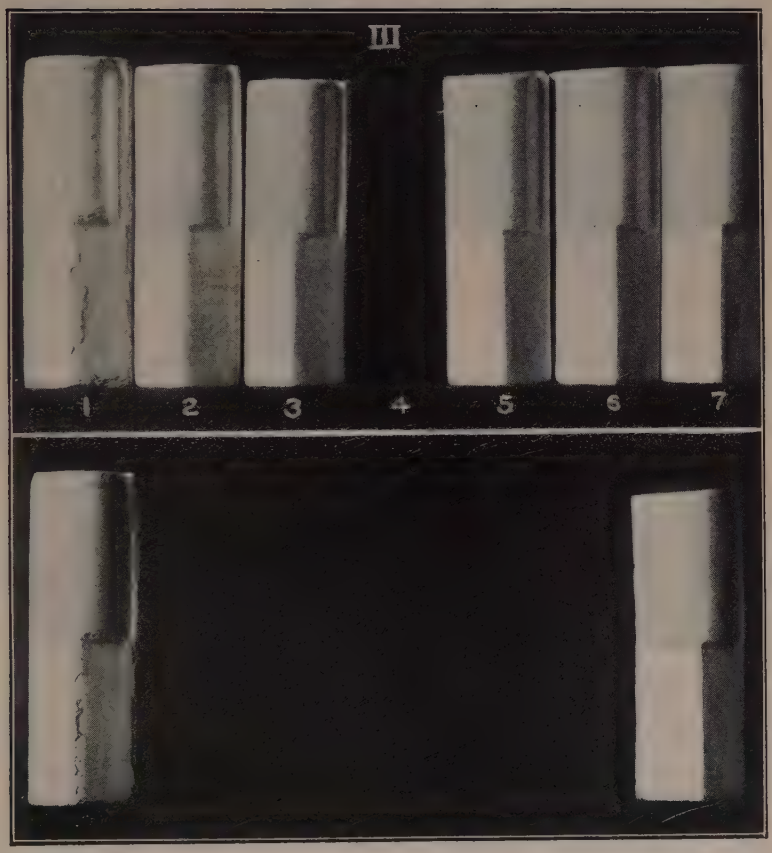
In discussing the above results, it might be well for purposes of comparison, to refer to our transactions, page 136, of Volume II, in which A. R. Griffin makes some of the most remarkable statements that have come under the writer's observation.

In case 3, therein mentioned, is to be found the following statement: "Repeated addition of silicious clay to a vitrifying clay causes it to pass from standing to crazing, then to standing, then to shivering, glaze and heat being the same."

Presuming that the writer in the first clause of the above article was speaking of bodies and not single clays, and that he was adding silica to a vitrifying body, the results as given in my experiments would seem to prove the contrary to be true, for in no instance does the increase of silica in the body, even when carried from 10% in No. 5, to 60% in No. 5, series I, produce crazing, the heat being not over cone 10.

Considering them not as bodies but as clays which have been mixed, my experience has likewise been contrary to the results cited above. By repeated addition of silicious clay to a vitrifying clay I have had it pass from crazing to standing, then from standing to shivering, then to a mixture that would not hold the glaze at all.

In reversing, thus: Adding a vitreous clay to a silicious clay, it has passed from shivering to standing, then to crazing, but in repeated additions it continues to craze to the end.



Series 3. Upper series fired to Cone 10. Lower series to Cone 14. No. 1 shivered at both temperatures. Others stood.

In case 5, same paper, is found the following: "Increased heat given a body caused it to pass from shivering to standing, then to standing, then to crazing, then to standing, the glaze being the same."

In the trials here submitted, where the silica was high enough to cause shivering, increased heat, though it improved, did not remove the trouble, but where the silica was not high enough to cause shivering, increased heat, though the silica was still high, caused it to craze by over-fire.

The lighter pieces in series I, it will be noticed, do not show any peeling, due to the fact probably that the glaze did not reach the edges of the pieces. (*March, 1905, all members of series are shivered in the larger pieces.—Editor*).

In series II, however, where English china clay is substituted for Florida clay, and stone for spar, even the small round pieces shivered badly, especially where the flint reaches as high a content as 45% of the total mixture.

Nos. 3, 4 and 5, of series I, which peeled badly in the heavier pieces, were subjected to heat as high as cone 14, but peeling still remained, though modified somewhat. (*2, 3 and 4 crazed.—Editor*).

In the light of the above, does increased heat make a low heat shivering body safe? I would answer "no," but to make it safe, increase the spar at the expense of either clay or flint until it has reached a point not less than 20% of the whole mixture, and as in No. 3, series III, it can be raised as high as 35% and a safe hard body will result, fired at cone 10.

In summing up the points that seem to be brought out in these trials, we might say:

First: Where the spar is as high as 20% of the total mixture no peeling will ensue, regardless of the quantity of quartz used, providing it does not exceed 50% of the total mixture, if fired at cone 10.

Second: That it is safe to use as high as 40% of spar, the silica not being lower than 20%, without fear of crazing, fired at cone 10.

DISCUSSION.

Mr. Weelans: It is seen from the formula here that the first object was to increase the silica merely to show where the shivering began and near the point where it ended. In series II, Cornish stone was substituted for feldspar. Again, we used a proponderance of china clay. Numbers 1, 2, 3 and 4, of series II, peeled more than the like numbers in series 1.

Mr. Orton: The constitution of one and two is the same except in choice of ingredients?

Mr. Weelans: Yes, sir; we substituted stone for spar, and used more English china clay and less Florida clay. In series III the object was to start with peeling and to go down, starting at the shivering point. As we go down the series we obtain a good hard body, practically semi-vitreous.

I would like to call your attention to the results obtained when changing from a smaller to a larger quantity of feldspar. Every trial containing 10% of spar peeled; on increasing the spar to 15%, no peeling was observed, no matter how the other ingredients were changed.

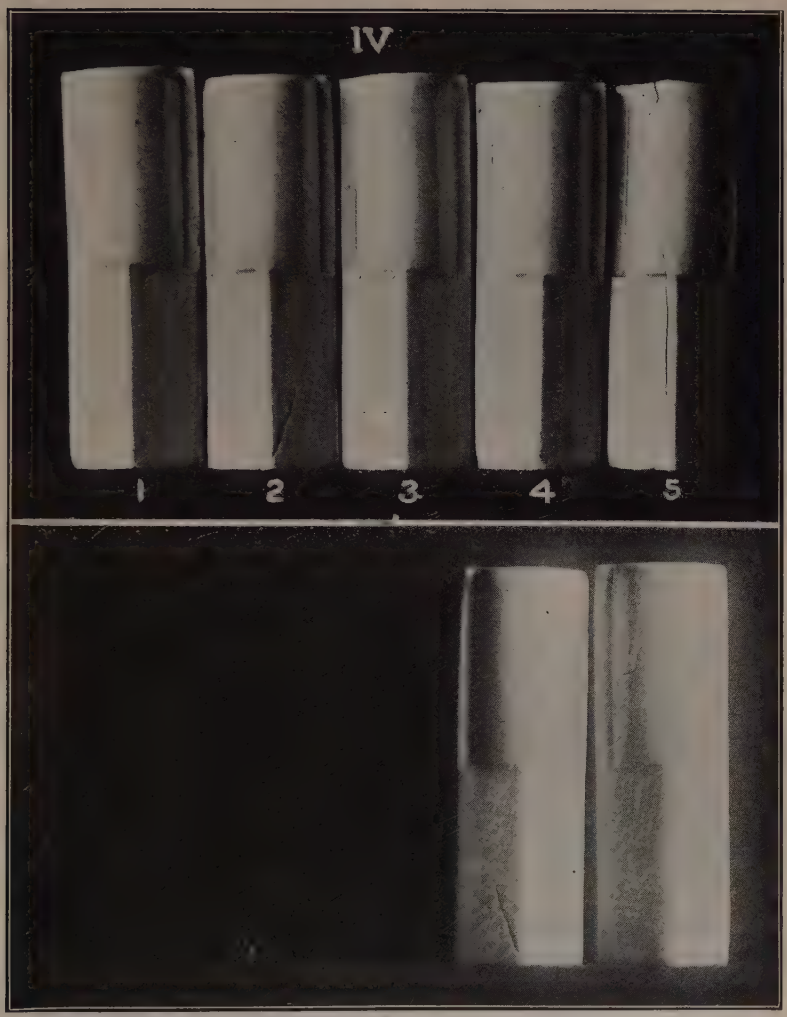
Mr. Orton: In which series does that appear?

Mr. Weelans: In series IV. Here I say, we increase the flint; but we also have 15% of spar. The result is that no peeling shows at all. Then by the time we reach the end of this series, we have 70% of clay. We expected to find crazing, but it did not take place at the time of writing this article. I would like to be told the reason why.

In the next series, V, we started with 60% of flint and 10% of spar. By reducing the silica 10% and increasing the spar 5%, peeling stops. We have samples of each series, in one and two fires, the trials being similar in character.

Mr. Geijsbeek: Are the series of two fires, biscuit and glost, at the same heat?

Mr. Weelans: Yes, sir; practically the same. Some of the pieces we took up to cone 15, which we naturally



Series 4. Upper Series fired at Cone 10. Lower Series at Cone 14. Both stood.

supposed would prevent peeling; but in no instance was it prevented entirely. These extra pieces (indicating) we put through out of curiosity.

Mr. Stover: Prof. Orton sent out a paper on the same line, of trials made four years ago, a paper by Mr. Purdy, and I think it is on the program. A great many points brought out in these experiments coincide exactly with those of the Purdy paper; in fact, I do not think they contradict any points in Mr. Purdy's paper.

Mr. Weelans: The only difference is that Mr. Purdy used ball clay. I did not use ball clay.

Mr. Stover: The Purdy trials were fired at lower heats; the first fire at cone eight, and glost at cone six, using the same glaze in each case. The question of shivering and peeling, and the samples that stood, seemed to be within the same range of body composition, in both papers, which we can see when we get both papers.

Mr. Burt: Are those pieces dry pressed?

Mr. Weelans: They are made from soft clay, such as the potter uses generally—in other words, fully saturated with water.

Mr. Gates: Are those round samples different?

Mr. Weelans: They are the same, only we made them up in two or three different shapes to see whether the different forms would remove any of the tendency to shiver.

I would like to say further that I ascribe the fact that series II went before series I to the substitution of Cornish stone for feldspar, because we were increasing the silica in doing this.

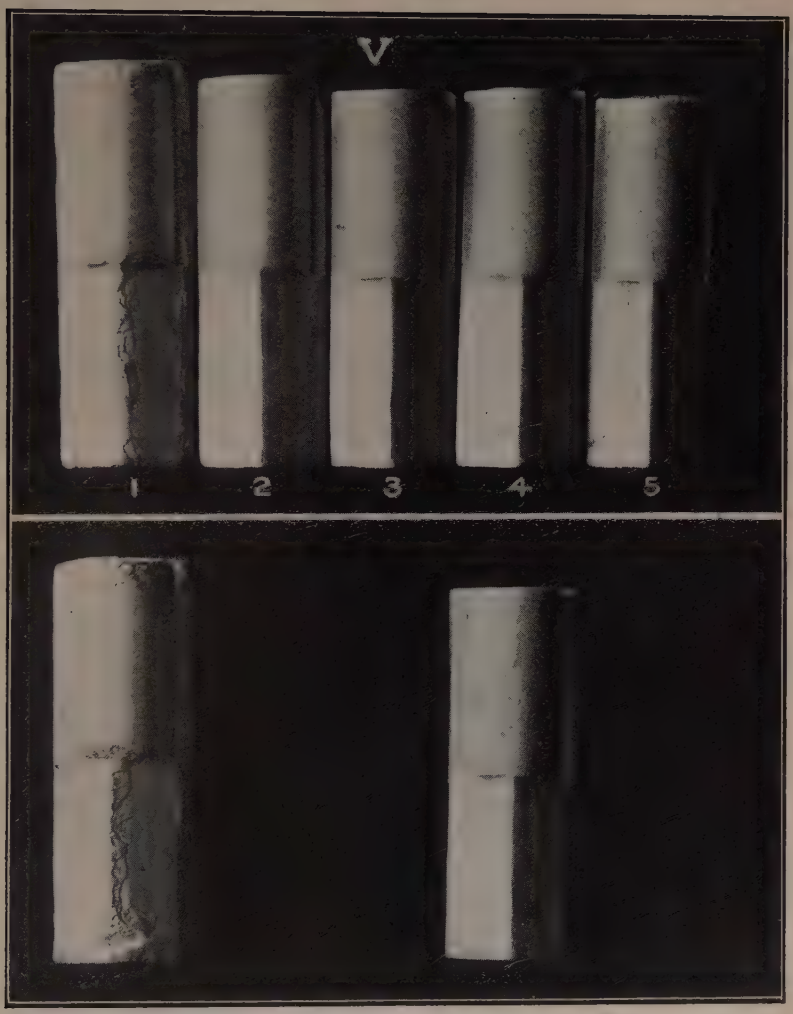
Mr. Geijsbeek: I think this paper is very interesting and instructive. We have Seger's law about shivering and crazing. The laws he laid down—he does not mention the fact, but nevertheless it is there, apply to a twice burnt piece of ware, biscuit first at high heat and afterwards glost at a softer heat. It will be interesting to note these laws which Seger laid down applying to biscuit bodies, whether they will work the same on a green body fired

in one fire. Mr. Weelans finds in his experiments that an increase of flint produces shivering. He further finds that an increase of feldspar decreases shivering, which conclusions are the same as Seger's law for biscuit bodies. He finds, however, that an increase of the plastic binding material or clay substance, by using kaolin, produces shivering, which is not in accord with Seger, who says that an increase will overcome shivering. As Mr. Weelans does not use a ball clay, the effect of a substitution of the clay substance from a plastic clay by that derived from kaolin, can not be observed in these experiments.

Taking these points together, we find that Seger's laws about crazing and shivering in connection with changing the body, the glaze remaining the same, are the same for green as for biscuit bodies as long as the changes are made with non-plastic materials, flint and feldspar, but results are different by the interchanging of clays.

Further experiments on this subject would be necessary in order to come to some definite conclusions as to that difference. That crazing did not set in, in his series No. IV, with high percentage of clay, is certainly due to these same facts that the clay substance works differently in regard to shivering and crazing on glazed bodies, which are first burnt biscuit, than on bodies which are glazed and burnt all in one fire.

The matter of substituting stone for feldspar, without paying any attention whatever to their chemical compositions, brings out a fact which we encounter in practical work. We may get the same result by a meré substitution of stone for spar, and we may not. We know in a chemical way, it is an entirely different proposition. Mr. Weelans' experiments show that very plainly, because he cannot get the same results. Therefore, a mere substitution of these ingredients without any knowledge as to the composition of stone or spar, is a cut and try method of the rankest kind. It is just such experiments as Mr. Weelans brought out, that are designed to convince the practical fraternity that chemical knowledge is necessary in order even to obtain practical results.



Series V. Upper Series fired at Cone 10. Lower Series at Cone 14. No. 1 shivered at both temperatures. Others stood, except No. 5, which crazed at higher temperature.

I congratulate Mr. Weelans on the effort he has made in order to bring the white ware question before the society, and show practical results of those things which he finds in practical work, and which are a check upon the scientific researches which we are now making in laboratory work.

Mr. Binns: Mr. Weelans claims that these experiments are made with commercial materials and on a practical scale. There are many advantages in experimenting in a manufactory, but I wish to point out that in school work we also use commercial materials. It is true that we analyse our materials in order that we may know what we are using, but no effort is made to procure anything different from that obtainable by potters. Quite the contrary, in fact we seek to get the usual and commercial article.

Mr. Purdy: There are three important facts brought out by Mr. Weelans' experiments:

First, that under some conditions, increase in glost firing will change the glaze from shivering to crazing. This was shown in nearly every instance where he fired his glazes to cone 14, and most particularly in series IV. In all cases of pieces, glost-fired at cone 14, the body continued to shrink and vitrify to a far greater extent than it did when glost fired at cone 10. This is not a matter of uncommon experience, for at each repeated firing at any given cone above 01, where feldspar begins to react, the body will continue to shrink as it would if carried on up to a higher cone in the one normal firing. This raising of the coefficient of the glaze over that of the body by increasing the glost heat is opposite to the common experience of glaze makers. That it will occur has been proven by Weelans and Dr. Hecht. Can it be due more to the excessive heat used in the glost firing, lowering the coefficient of the body so rapidly as to develop this phenomenon? This is certainly an interesting point.

Secondly, series II illustrates very nicely the fact that the substitution of Cornwall stone for feldspar in the

body, pound for pound, will counteract the crazing glaze.

Thirdly, Weelans' experiments bear out the evidence that Seger's law will not operate within the close limits ascribed to them.

I offer these remarks because Mr. Weelans did not emphasize them sufficiently.

DISCUSSION ON "SOME EVIDENCES THAT BODIES HIGH IN SILICA CRAZE BY OVER-FIRE."

BY

HARRISON EVERETT ASHLEY, East Liverpool, Ohio.

The present writer, having found it easier for himself to comprehend the results of experiments when they are expressed by diagrams, has prepared two diagrams representing Mr. Weelans' valuable experiments.

The form of diagram chosen is that known as the triaxial diagram, which has already been used by Le Chatelier to exhibit the properties of ceramic mixtures, by Howe, and by Ashley for slags, etc. It is applicable to mixtures of three substances, whose sum is a constant. For plotting, I will take the total clays, the flint and the feldspar as equal to the constant sum, 100 per cent.

In the diagram for the cone 10 glaze burn, I will let the base of the triangle represent zero per cent. feldspar, the apex 100 per cent., and any intermediate horizontal line a percentage proportional to its distance from the base to the vertex. Horizontal lines are drawn in the diagram for 20, 40, 60 and 80 per cent. feldspar. Trial 5, of series 5, is on the horizontal line representing 40 per cent. feldspar.

In the same way the right hand side of the triangle will represent zero per cent. of clays, the opposite lower left hand corner 100 per cent., and intermediate lines parallel to the right hand side the intermediate percentages of clays. Trial 5, of series 5, and trial 1, of series 1, each contains 50 per cent. of clay, and are half way from the right hand side to the lower left hand corner.

Finally, the left hand side of the triangle represents zero per cent. of flint, the lower right hand corner 100 per cent., and intermediate lines parallel to the left hand side intermediate percentages of flint. Trial 5, of series 5, has 10 per cent. of flint, and is 10 per cent. of the distance from the left hand side to the right hand corner.

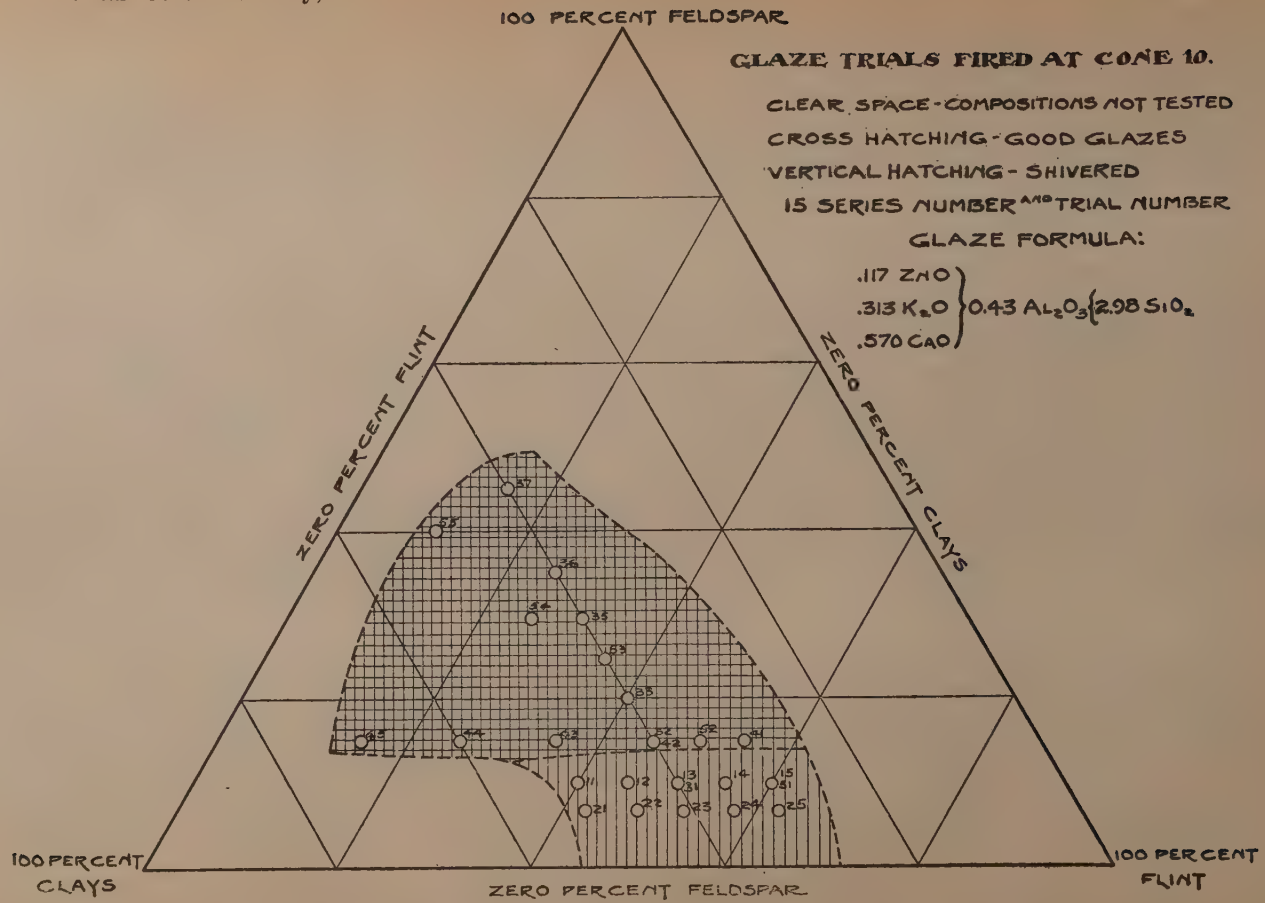


Fig. 1. Triaxial Diagram Showing Weelan's Results of the Cone 10 Burn.

In other words, if any point in the triangle is taken, its distance from each of the three sides will give a percentage of each of three components, and the sum of the three will always be found to be 100 per cent. The triangular diagram will represent all possible mixtures that can be formed between clays, feldspar, and flint. Each point represents a different mixture.

I have surrounded the area covered by Mr. Weelans' tests with a dotted line. Where good glazes were found, there is a vertical and horizontal cross-hatching. Where shivering occurred, there is vertical hatching alone, and (on the cone 14 diagram) where crazing occurred, there is horizontal hatching.

In the diagram representing the results at cone 14, exactly the same explanation holds as for the cone 10 diagram.

To bring series 2 more closely into agreement with Mr. Weelans' other data, and permit its being plotted in the same diagrams, I have made the unscientific assumption that Cornwall stone is composed of feldspar, kaolin and flint, and have made a recalculation on that basis. For this purpose I have not used the formula of Cornish stone given in the "Manual of Ceramic Calculations," but one kindly supplied by Mr. Ross C. Purdy, which he had prepared by averaging the analyses of twelve different samples, viz:

	.38 CaO	.62 KNaO	1.34 Al_2O_3	9.7 SiO_2	.82 H_2O
Assumed spar	.38	.62	1.00	6.0	
			.34 Al_2O_3	3.70 SiO_2	.82 H_2O
Assumed kaolin			.34	.68	.82
Assumed flint				3.02 SiO_2.	

The combining weight of this formula is 803, assuming 78 as the molecular weight for KNaO.

This gives feldspar 66.6, kaolin 1.1, silica 22.3, and the formulæ of series 2 become:

No.	Clays	Flint	Feldspar
1	51.11	42.23	6.66
2	46.11	47.23	6.66
3	41.11	52.23	6.66
4	36.11	57.23	6.66
5	31.11	62.23	6.66

None of the trials fired at cone 10 crazed. All trials with less than 15% feldspar shivered. All with 15% or more of feldspar were good. The worst shivering was with the highest flint and low clay. While shivering occurred with from 40 to 62 per cent. flint, good glazes were on bodies with from 10 to 55% flint. With clay percentages varying from 30 to 50%, both good and shivered glazes were obtained throughout the entire range. So while a fairly high flint, and a very low clay content are necessary conditions for shivering, together with these must go a low feldspar content, less than 20%, Mr. Weelans finds.

The over-firing of glaze trials to cone 14 made a marvellous difference. The tests show that with ten or more per cent. of feldspar in the body, the glaze crazed in every case. With the feldspar under 7 per cent. two bodies still shivered, one body, (No. 3 of series 2) took a good glaze, and one other (No. 2 of series 2) was either good or very slightly shivered. (The present writer is not able to say which. The small piece of glaze may have been cracked by accident).

I must dissent from the conclusion that the increased peeling of series 2 is partly due to "increasing the English china clay at the expense of the Florida," for I think the change from feldspar to Cornish stone not only "assisted," but is the main cause of the difference of the two series. The recalculation of stone into spar, kaolin and flint showed to me that the feldspar constituents were only two-thirds as much in series 2 as in series 1, while the clay totals were but slightly different. The feldspar content being the thing most different between the two series

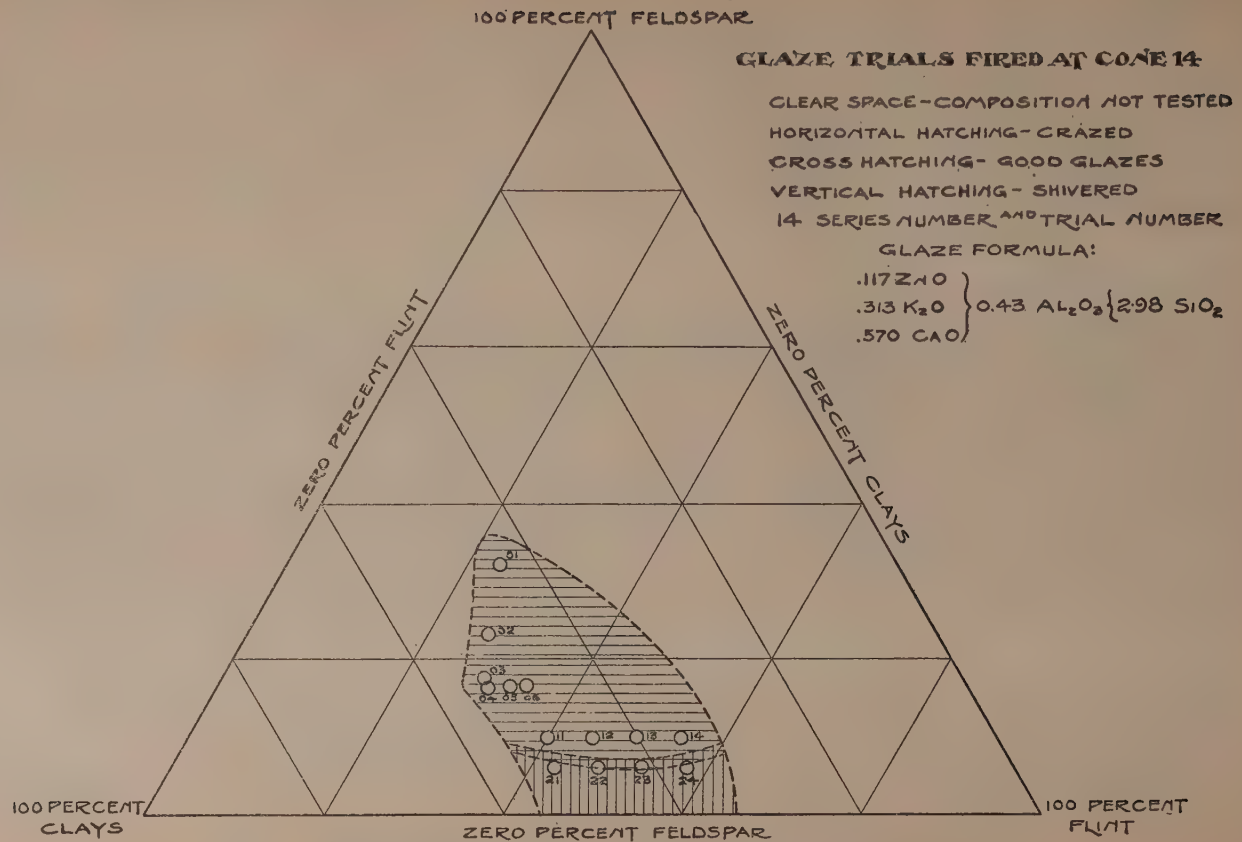


Fig. 2. Triaxial Diagram Showing Weelans' Results of the Cone 14 Burn.

semed to account for the difference in peeling. This belief was confirmed by comparing No. 2, of series 3, with No. 2, of series 4. These two bodies have the same flint, spar and total clays, but No. 2, of series 3, has the larger proportion of English china clay and is a good glaze, while No. 2, of series 4, with less English clay and more Florida clay, is also good. The two tests are so near the limit where shivering begins, that one would likely have shown it if there were any marked difference.

Again, No. 1 of series 3 and No. 3 of series 1 have the same flint, spar, and total clays; but the former has 20% English and 20% Florida clay, the latter 15% English and 25% Florida clay. Both have the edges shivered to the same extent.

Mr. Weelans' summing up is so definite in its recommendations that the question comes up at once, "Can it be applied in practice with other glaze formulæ?"

Many glazes have but a limited temperature range in which they are good, smooth, and bright; so that apart from the danger of crazing, other causes would make overfiring undesirable as a cure for shivering.

While all Mr. Weelans' tests were biscuited at cone 14, the contraction is much more marked with many of the tests glazed at the higher temperature with resulting altered properties, as shown in the following table:

Series No.	Trial No.	Fired length in inches Cone 10 glost	Remarks	Fired lengtn in inches Cone 14 glost	Remarks
1	2	5.84	Shivered	5.65	Crazed
1	3	5.89	Shivered	5.77	Crazed
2	1	5.94	Shivered	5.65	Slightly Shiv.
2	2	5.94	Shivered	5.67	Uninjured

The glazing at the higher temperature not only carried the contraction further, but made the bodies much more porcelain-like in structure.

In Purdy's paper, series 4, all burnt at the same temperature, the two members with highest kaolin content contracted much more than the others, and crazed, al-

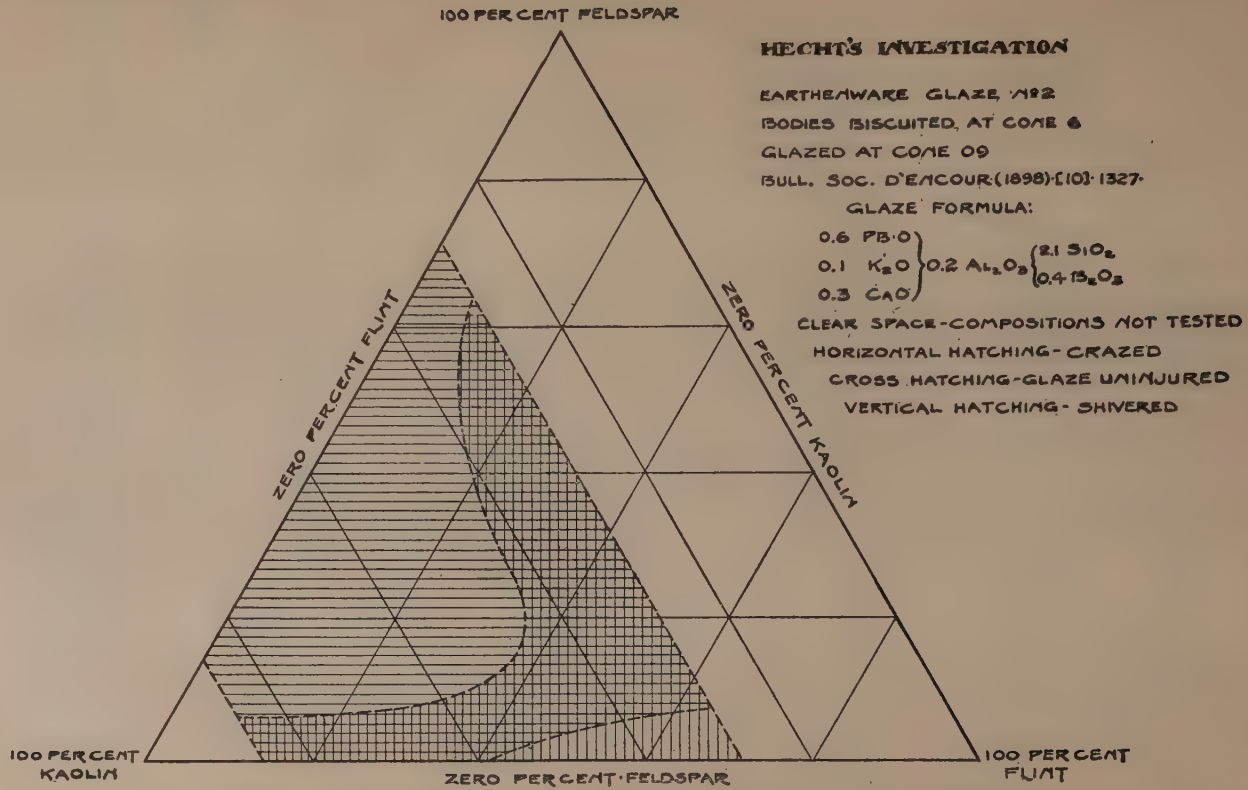


Fig. 3. Triaxial Diagram Showing Hecht's Results with Cone 6 Biscuit.

though the flint, feldspar and total clays were the same throughout the series. Seger made a similar series, without feldspar, with crazing at high ratios of kaolin to plastic clay.

Consequently, a whiteware glaze cannot be used when the temperature of firing the glaze or the composition of the body develops a porcelain-like structure, on account of crazing. This has been explained by Burt.

With reference to the limits of crazing and shivering found by Mr. Weelans, a comparison with the results by Dr. Hecht is interesting. His investigations, originally published in German, translated into French, but not yet into English,† were upon wide variations in body composition, keeping the glaze the same throughout. He did this extensive work for each of five quite different glazes, none of which very closely resemble Mr. Welans' glaze. Three of these were upon the same series of bodies, biscuited at two different temperatures. No two glazes behaved the same; that is, on the cone 6 biscuit, the limits of crazing and shivering were different for each glaze. With one glaze, higher biscuit fire (cone 10) increased the shivering, with another it decreased the shivering. Mr. Weelans' limits, therefore, are of value as showing about what may be expected with a glaze of the type used by him, but must not be applied to glazes of very different type.

Diagrams giving Hecht's results on one of the five glaze are reproduced to accompany this discussion.

Mr. Purdy's paper, published in this volume, also shows limits different from those obtained by Mr. Weelans.

Seger's tables, pp. 607 and 608*, also show different limits for crazing and shivering, according to the glaze used.

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†Thonindustrie Zeitung (1897), 21, 738. Bull. de la Soc. d'Encouragement, etc. (1898) series 5, 3, 1321. (The diagrams of this discussion are made uniform with those of the excellent French presentation.)

*Translation of Seger's Collected Writings.

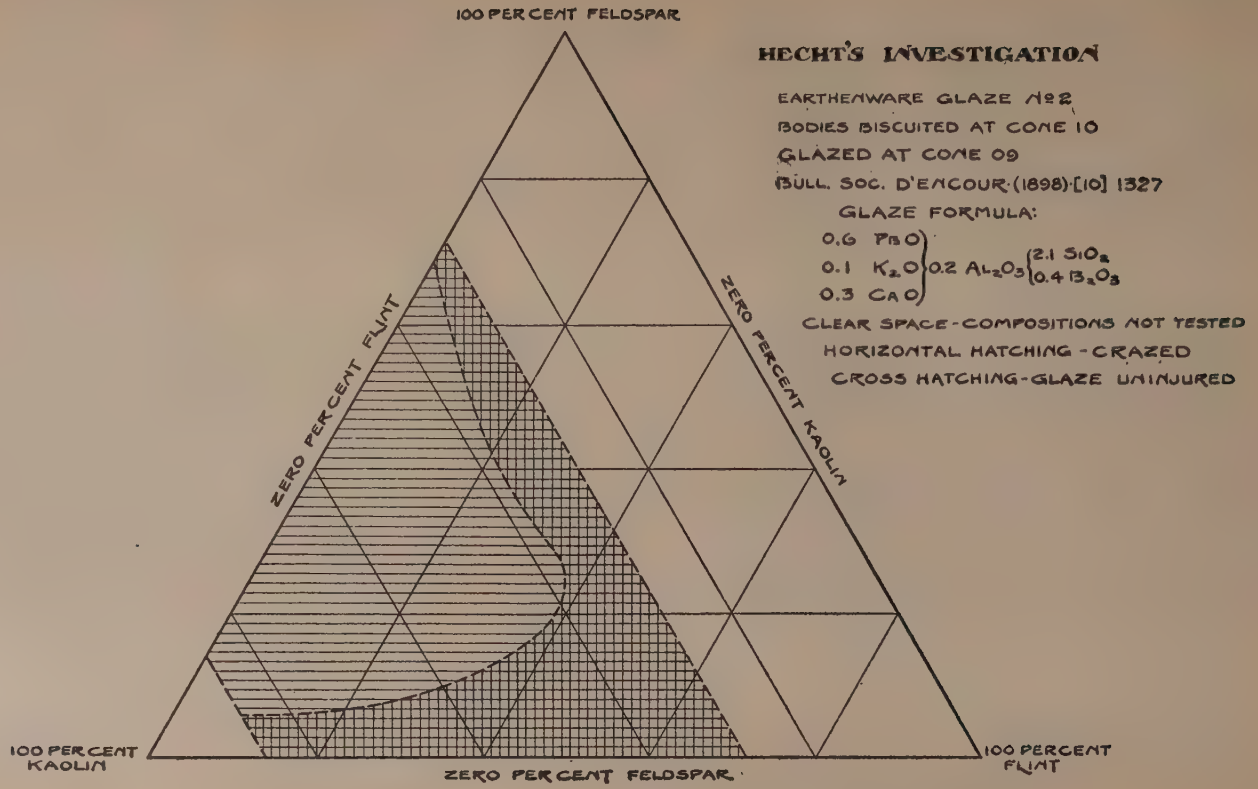

Fig. 4. Triaxial Diagram Showing Hecht's Results with Cone 10 Biscuit.

The combined results of these four investigations show:

1. That crazing is most likely to take place with low flint, high clays, and from 20 to 30 per cent. feldspar, further increase or decrease of feldspar tending to decrease the liability.

2. That shivering, when it occurs, takes place with low feldspar, and is further promoted by high flint and low clays.

3. That harder burning of the body may increase or decrease the tendency to shiver.

4. That changing from a white ware to a porcelain-like structure will produce crazing, whether the change be brought about by higher glost fire (Weelans), or increasing the ratio of kaolin to plastic clay (series 2, Purdy).

THE LIMITS OF VARIATION IN BISCUIT BODY COMPOSITION.

BY

R. C. PURDY, Columbus, Ohio.

It has been thought that Seger's laws, relative to the correction of crazing and shivering in a glaze by variations of the body composition, operated within close limits. The writer, sometime ago, made several experiments in biscuit bodies, the results of which were in seeming contradiction to this view, and hence offers the following account of these experiments for discussion.

On page 575, Volume II, Seger's Collected Writings, we read: "We will notice that either no crazing, or at least but small cracks, appearing slowly, will be found on those tests which contain the least clay substance, and that the crazing increases in proportion as the content of clay substance increases."

On page 576, we read "If we add in place of the Zettlitz kaolin, another binding material, which is more plastic, we will arrive at the same results, with this difference, that in tests of equal clay content those which contain the Zettlitz kaolin craze worse in the glazing than those which contain more plastic clay. An addition of plastic clay therefore decreases the coefficient of expansion, though in less degree than the less plastic kaolin clay."

Further: "We will find that crazing occurs worse in those which are the highest in feldspar, and that it decreases gradually with the decrease of feldspar."

Further: "If we increase the quartz content, the crazing grows less and less, and finally disappears altogether, and finally shivering appears."

Seger's tables, given on pages 607-608, Vol. II, of the translation of his "Collected Writings," show his results graphically, and a study of them will disclose the fact that even his results do not confirm entirely the usual interpretation of the limits of variation in body composition

suggested by his laws. He, himself, draws the conclusions (p. 608) that in order to obtain stable glazes, only *slight* room for the variation in the composition of the white ware body is admissible. The natural conclusion based on experimental evidence at hand, would be that there is considerable room for the variation in composition.

He very tactfully qualifies his conclusions by stating "It is further concluded that the room for variations admissible in the composition of the body is the less, the more fusible the glaze is, and the greater, the more difficultly fusible it is."

From practical experience, the writer knows that some glazes do not permit of a wide variation in body composition, while others do. The glaze given by Mayer, on page 57, Vol. I, of our Transactions, is a glaze that does, and the glaze used in the experiments now to be described is another. What property gives these glazes this wide range is a question which cannot be discussed at this place. It remains a fact, however, that the glaze used, may be a cause of the wide limits of variation in body composition here shown.

Notwithstanding the fact that my results seem to be at variance with Seger's laws and conclusions as quoted, I am not disposed to question the substantial truth of the latter, for I have noted in my experience that they generally do hold. But these occasional cases which do not seem to agree with Seger's laws, raise the question as to what are the causes of this irregularity or variation in the permissible limits of body composition.

We are continually learning more of the laws of silicate reactions. We cannot expect to be able, at least not soon, to lay down rigid rules, because we lack methods of measuring their effects. There is no doubt, however, that with the search light of physical chemistry, we shall ultimately penetrate the mystery of these laws to a greater degree of accuracy than by any other means. Until we do this, we must be content with deductions drawn from the empirical results of various experimentors. It is with this

idea that the writer submits this note for your consideration.

The trials in the following series were dry pressed, biscuited at cone 8, and glazed at cone 1 under commercial conditions. The body ingredients used were: New Jersey ball clay, purchased from C. S. Edgar; American kaolin, from Chester, Pa.; Golding flint, and Brandywine feldspar.

The glaze used in these experiments was:

$$\left.\begin{array}{l} 0.49\ PbO \\ 0.12\ K_2O \\ 0.15\ Na_2O \\ 0.24\ CaO \end{array}\right\} 0.19\ Al_2O_3 \left\{\begin{array}{l} 0.571\ B_2O_3 \\ \\ 2.25\ SiO_2 \end{array}\right.$$

In dipping, the attempt was made to give each trial the same thickness of coat, but in this way we have failed, for the bodies varied considerably in density.

Nothing is given of the difference in total shrinkage, and density, for these factors are not considered as bearing on the question under discussion. These factors would require consideration if the variations in total shrinkage and density were functions of the difference in heat treatment, instead of difference in body composition.

Biscuit Bodies.

Series No. I.

Batch Formula					Chemical Formula		
No.	Ball Clay	China Clay	Flint	Spar	K_2O	Al_2O_3	SiO_2
6508	20	10	37	6	0.0848	1.0	7.191
6507	20	15	37	6	0.0736	1.0	6.505
6506	20	20	37	6	0.0649	1.0	5.977
6505	20	25	37	6	0.0582	1.0	5.562
6504	20	30	37	6	0.0527	1.0	5.225
6509	20	40	37	6	0.0443	1.0	4.711
6510	20	50	37	6	0.0381	1.0	4.332
6511	20	60	37	6	0.0336	1.0	4.060
6512	20	70	37	6	0.0299	1.0	3.833
6513	20	80	37	6	0.0270	1.0	3.654

REMARKS.

All trials stood for four years in an attic without crazing. Shrinkage increases slightly with increase of china clay, but not causing much difference between the two extremes.

DISCUSSION OF SERIES I.

In Series I, the clay content varies from 69.93% to 41.09% of the total body content. This, it must be remembered, is not equivalent to saying that the clay substance varies between such extremes. The variation of actual clay substance in this series could be figured from a rational analysis of the clays used, but unfortunately such data is not at hand. However, the variation in clay substance would be more than Seger's laws would *seem* to warrant, and we should expect crazing to appear on the bodies highest in clay, and shivering on those lowest in clay content.

The results shown in this series might have been in part explained, had the ball clay been varied instead of the china clay, for Seger's second law states that china clay, in the body, has a greater tendency than ball clay toward causing crazing. The fact is, that in Series No. 1, the bodies highest in kaolin are the lowest in actual percentage amounts of ball clay, and according to Seger's laws, should have a still greater tendency to craze the glaze for this reason.

In Seger's table A, page 607,* the limits of variation in clay substance vary from 10 to 25 percent, depending upon the glaze used. According to this there is not a great difference between the results developed by Seger's tests and those just given.

It is evident that the crux of the whole matter lies in the interpretation of the phrase of *slight variation.* To many, the limits of variation suggested by this term are considerably closer than either Seger's data (table A) or my own would indicate.

Laying aside all consideration of the laws governing

* Seger's Collected Writings.

the limits of variation in body composition, or even their effect on shrinkage and fusibility, would it not seem impossible that the body mixer may add ten pound or eighty pounds of china clay in a charge of 63 pounds of other materials, without affecting the behavior of the glaze so far as the fitting is concerned?

Factory experience has taught the writer, in spite of the testimony of these trial pieces, that it does, but it was thought that the difference lies not so much in the actual body composition per se, but, in case of the higher clay bodies, in their proximity to the critical point of crazing, so that if burned at a heat lower than that which is normally required, crazing will ensue. Absolute uniformity of heat throughout a kiln, or from burn to burn, is almost an impossibility under commercial conditions. Therefore, because of this irregularity in the heat treatment, it does matter whether 10 or 80 pounds of china clay is added to a charge.

This is in agreement with Seger's experience.[1]

Series No. II.

Batch Formula					Chemical Formula		
No.	Ball Clay	China Clay	Flint	Spar	K_2O	Al_2O_3	SiO_2
6514	20	37	37	0.00	0.0000	1.0	4.79
6515	20	37	37	6.00	0.0464	1.0	4.847
6516	20	37	37	10.00	0.0748	1.0	4.877
6517	20	37	37	15.00	0.108	1.0	4.913
6518	20	37	37	20.00	0.139	1.0	4.953
6519	20	37	37	25.00	0.168	1.0	4.988
6520	20	37	37	30.00	0.195	1.0	5.025
6521	20	37	37	45.00	0.266	1.0	5.102
6522	20	37	37	50.00	0.288	1.0	5.137

REMARKS.

Nos. 6514-6516 stood for four years in attic without crazing. Nos. 6517-6522 crazed at time of drawing kiln.

DISCUSSION OF SERIES II.

Comparing Seger's series C with series II it will, again, be evident that, while the permissible variation in

[1] Translation of Seger's Collected Writings, p. 577.

the content of feldspar is dependent upon the glaze used, Seger's law governing the variation of feldspar in a body is, in general, true. In this respect the results given in series II corroborate Seger's results, but in neither series do the limits seem so narrow as Seger's statement seems to imply.

Series No. III.

Batch Formula					Chemical Formula		
No.	Ball Clay	China Clay	Flint	Spar	K_2O	Al_2O_3	SiO_2
6527	20	37	0	6	0.0463	1.0	2.182
6526	20	37	5	6	0.0463	1.0	2.265
6525	20	37	15	6	0.0463	1.0	2.432
6524	20	37	25	6	0.0463	1.0	2.598
6523	20	37	30	6	0.0463	1.0	2.682
6528	20	37	45	6	0.0463	1.0	2.932
6529	20	37	55	6	0.0463	1.0	3.083

REMARKS.

Nos. 6523, 6524, 6528 and 6529 have not crazed after four years in the attic. No. 6525 crazed sometime during the four years. Nos. 6526 and 6527 crazed at time of drawing the kiln.

DISCUSSION OF SERIES III.

While the results shown by this series substantiate, in general, Seger's law governing the effect of varying amounts of quartz (flint), yet the limits of permissible variation are here also wider than the statement before quoted would naturally imply.

Series No. IV.

Batch Formula					Chemical Formula		
No.	Ball Clay	China Clay	Flint	Spar	K_2O	Al_2O_3	SiO_2
6532	5.0	52.0	37	6	0.0464	1.0	4.847
6531	12.0	45.0	37	6	0.0464	1.0	4.847
6530	17.0	40.0	37	6	0.0464	1.0	4.847
6533	25.0	32.0	37	6	0.0464	1.0	4.847
6534	27.5	29.5	37	6	0.0464	1.0	4.847
6535	30.0	27.0	37	6	0.0464	1.0	4.847

REMARKS.

Nos. 6530, 6533, 6534, 6535 stood four years in the attic without crazing. No. 6531 crazed sometime during the four years. No. 6532 crazed at time of drawing the kiln.

DISCUSSION OF SERIES IV.

It would be difficult to compare this series with any of Seger's, for he varied the kaolin at the expense of some one other constituent, while in this series, the total clay content and the content of feldspar and flint are held constant, the variations being made between the relative amounts of ball and china clay. This series, however, substantially bears out Seger's law governing this point.

GENERAL CONCLUSIONS.

We have seen in these results, as well as in Seger's, that:

(a) The glaze used is a function controlling the permissible variation in body composition.

(b) Seger's laws are not to be construed as operating within close limits under definite conditions.

(c) Owing to the many varying factors in commercial work, the bodies should be so compounded, according to Seger's laws, as to lie safely between the critical points of crazing and shivering of glaze.

(d) At present we have but little exact knowledge of the factors controlling the permissible variation in body composition, in so far as its bearing on the fitting of a particular glaze is concerned.

DISCUSSION.

Prof. Binns: I would like to ask Mr. Purdy whether he observed any evidence of the glaze feeding on the dry pressed body, whether the glaze was active at all in eating into the body.

Mr. Purdy: I did not look into this matter excepting to notice that the body admitting of the greatest variation crazed now and then. If the burning was done at a low heat the whole kiln of ware crazed, for owing to the more

porous body the glaze had more opportunity to eat into the body.

Mr. Binns: There you had an underfired body.

Mr. Purdy: Yes, on the other hand, if we went too high there was a disturbance. We did not observe any shivering whatever.

Mr. Binns: The question is frequently asked: "How is it, if it is possible to overcome crazing, that all the tile ever made craze?" Of course, I do not agree that this is strictly the fact, but much of the tile we see are badly crazed. I have found that if the tiles are kept dry they will not craze, even if subjected to variations in temperature, but as soon as they are set in cement or mortar they are liable to craze. Did you ever notice that, Mr. Purdy?

Mr. Purdy: I believe I have.

Mr. Walker: A very interesting illustration of the power of cement to cause crazing was exhibited in some glass shown me a few weeks ago. A gentleman came into my office with a piece of opalite glass cemented to a brick. The idea was to make an enameled brick which would stand the weather and not show cracking or crazing. His object was to fasten this piece of opalite tile to the brick with a weak cement. In this connection he showed me a piece of opalite tile about an eighth of an inch thick, set in cement, and a more beautiful piece of crazed ware I never saw. It was crazed all over—not cracked, but crazed, exactly as a glaze will craze when on a tile body.

Mr. Binns: I will ask Professor Orton whether he thinks there can be any chemical union between the glaze and cement?

Mr. Orton: I hardly think any chemical union takes place there; but I have been thinking, while the matter has been under discussion, that a possible explanation of it might be that the ordinary dry pressed tile is quite porous and absorbs fluids rapidly. When set in cement it would take up some of the water of the cement, perhaps not enough for complete saturation, but a good

deal. The water used in tempering the cement contains soluble salts, not only ordinary soluble salts, but probably some of the actual components of the cement, which are very much inclined to crystallize, since the setting of the cement itself is a process of crystallization. If we bring a lot of such material in the fluid form back of that glaze, and it proceeds to solidify and change volume, it will set up a new set of strains there which might result in cracking.

Mr. Walker: Prof. Binns is right in speaking of the difference in the behavior between a plastic and a dust pressed body. The glaze would absorb silica from the dust pressed body very quickly. As to the point raised in connection with the standing of the glaze when the tiles are kept dry and the crazing when set in cement, I think this observation is fully realized by experience. I have had tiles standing in the wareroom for five or six years without showing any signs of crazing, but when laid in cement they will craze in a short time.

Note sent in by Mr. Ernest Mayer, Beaver Falls, Pa.

It appears to me that when Seger speaks of "Another binding material which is more plastic," he refers to what we call a ball clay. What constitutes a "ball clay" is very difficult to determine and of the nature of *"a binding material which is more plastic"* actually used by Seger in his experiments, I have no knowledge at all. Those of us whose education in ceramics has been partly in England have a very definite and absolute knowledge of what is meant by the term ball clay, and for this reason, when Mr. Purdy in his paper speaks of ball clay purchased from C. S. Edgar, Metuchen, N. J., from my knowledge of this clay it cannot in any way be compared to what many of us, at least, understand to be ball clay.

I have repeatedly tried to use this and many other New Jersey ball clays, but they all lack the vitrification property, that it seems to me must accompany any clay that can be properly designated as a ball clay. If I have read Seger's articles understandingly, what he insists on

is, that on the appearance of crazing, he wants to get part of the vitrification of the body through the agency of the ball clay, at the expense of the feldspar, and in my experiments I can fully agree with his conclusions that it is the proper method to pursue. What I would understand as a true ball clay is one that will vitrify at a temperature not exceeding cone 5 or 6. There are many such clays to be found in the United States, notably one found at Regina, Mo., and also clay found in Kentucky, but unfortunately their use is prohibited in the very best ware on account of their color. I am using at the present time a clay mined in Tennessee, that is taking the place of English ball clay and fills the bill in every respect.

I try to keep in touch with the material that is being used by all the manufacturers in the west, and I cannot recall a single instance where Edgar's clay is being used to take the place of what is generally called ball clay among manufacturers of white granite and semi-porcelain ware, and the reason is very obvious; in the first place, it takes entirely too much fire to vitrify it; it is still absorbent at cone 8, and secondly, its tensile strength when dry is very low. For these two reasons it should never, in my judgment, be classed as a ball clay.

These remarks of mine do not in any way detract from the value of this splendid paper given us by Mr. Purdy, because I appreciate it as a most useful addition to our literature, but I have made these notes more with a view to bringing out an expression of what is really meant by this ambiguous term "ball clay," and see if it cannot be placed in a classification where it is properly defined.

DISCUSSION ON "THE LIMITS OF VARIATION IN BISCUIT BODY COMPOSITION."

BY

HARRISON EVERETT ASHLEY, East Liverpool, Ohio.

The writer has plotted Mr. Purdy's results by means of the triaxial diagram.

To do this, his batch weights were calculated over to percentages, as follows:

Series I.

No.	Ball Clay	China Clay	Flint	Feldspar
6508	27.39	13.70	50.68	8.23
6507	25.64	19.23	47.44	7.69
6506	24.09	24.09	44.59	7.23
6505	22.72	28.40	42.06	6.82
6504	21.49	32.27	39.78	6.46
6509	19.42	38.84	35.91	5.83
6510	17.70	44.26	32.73	5.31
6511	16.25	48.79	30.08	4.88
6512	15.06	52.62	27.80	4.52
6513	14.00	55.94	25.87	4.20

Series II.

No.	Ball Clay	China Clay	Flint	Feldspar
6514	21.27	39.37	39.36	....
6515	20.00	37.00	37.00	6.00
6516	19.23	35.58	35.58	9.61
6517	18.33	33.95	33.95	13.77C
6518	17.54	32.46	32.46	17.54C
6519	16.80	31.09	31.09	21.02C
6520	16.12	29.84	29.85	24.19C
6521	14.38	26.63	26.63	32.36C
6522	13.88	25.70	25.70	34.72C

C=Crazed.

Series III.

No.	Ball Clay	China Clay	Flint	Spar.
6527	31.73	58.75	.....	9.52C
6526	29.41	54.41	7.36	8.82C
6525	25.64	47.45	19.23	7.68C
6524	22.72	42.06	28.40	6.82
6523	21.49	39.78	32.27	6.46
6528	18.51	34.26	41.67	5.56
6529	16.93	31.34	46.64	5.09

Series IV.

Originally in Percents.

No.	Ball Clay	China Clay	Flint	Spar.
6532	5.0	52.0	37.00	6.00C
6531	12.0	45.0	37.00	6.00C
6530	17.0	40.0	37.00	6.00
6533	25.0	32.0	37.00	6.00
6534	27.5	29.5	37.00	6.00
6535	30.0	27.0	37.00	6.00

These computations were made with the slide rule; in this case the sum of instrumental and personal errors is liable to amount to one part in 900—an error too small to be of account here.

I will first consider series I, II and III. After plotting these on the diagram, I have attempted to draw the dividing line between crazed and uninjured glazes. So far as Mr. Purdy's data go to show, the line may occupy the position AB, DE or GBCDKL, or any intermediate position. To the extent of the difference between these two extreme lines, Mr. Purdy has failed in his object of showing the limits of variation in biscuit body composition, beyond which crazing takes place.

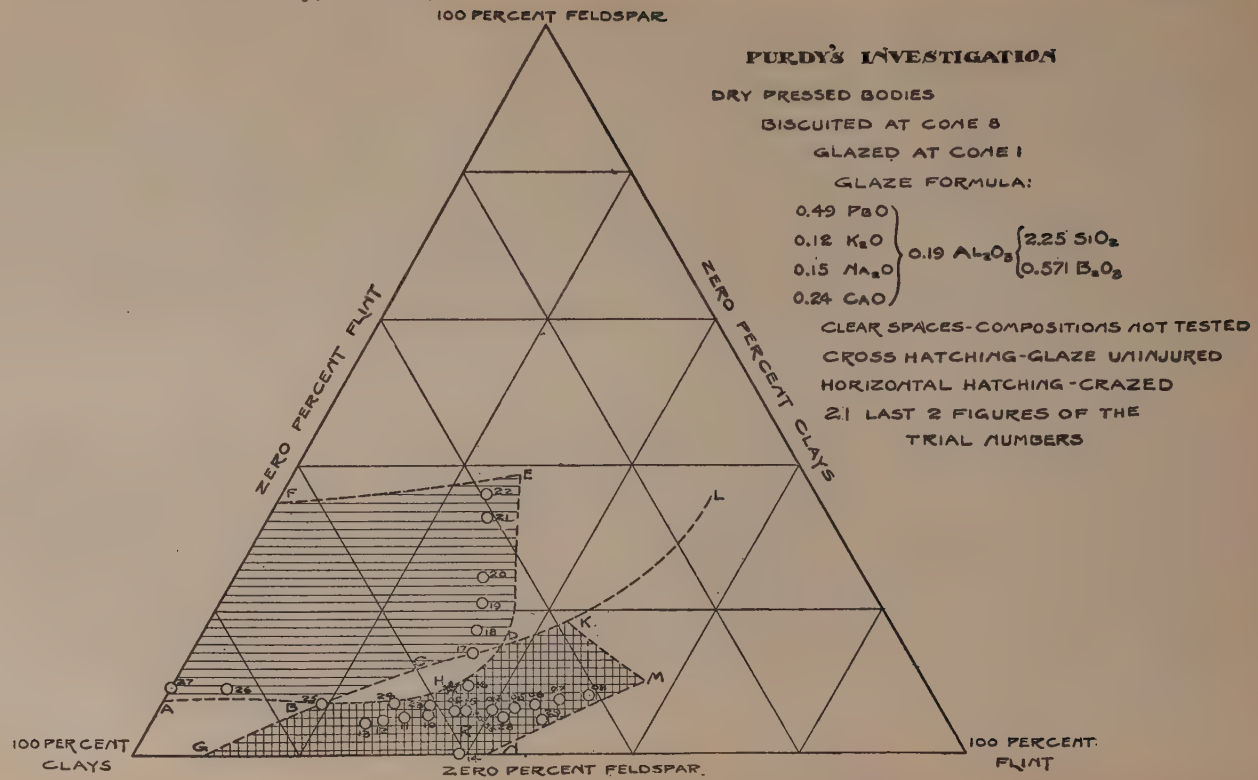

Fig. 5. Triaxial Diagram Showing Purdy's Results.

Purdy's glaze, fired at cone 1, is

$$\left.\begin{array}{l} 0.49\ PbO \\ 0.12\ K_2O \\ 0.15\ Na_2O \\ 0.24\ CaO \end{array}\right\} 0.19\ Al_2O_3 \left\{\begin{array}{l} 2.25\ SiO_2 \\ 0.571\ B_2O_3 \end{array}\right.$$

Hecht tested at cone 010 a similar glaze

$$\left.\begin{array}{l} 0.6\ PbO \\ 0.1\ K_2O \\ 0.3\ CaO \end{array}\right\} 0.2\ Al_2O_3 \left\{\begin{array}{l} 2.1\ SiO_2 \\ 0.4\ B_2O_3 \end{array}\right.$$

By comparison with the diagrams of Hecht's results, it appears most likely that ABHDE is the boundary between Purdy's crazed and uninjured areas.

That doubtful compositions (area BHDC) should occur so close to the range where the greater part of Purdy's work was done seems to me a serious defect. His tests appear designed to show the effect of deviations from a standard body composition, No. 6515; yet if we diminish flint 3%, and increase feldspar 3%, keeping the clay constant, we reach the point where crazing is liable to happen. But series II, on variation of feldspar alone permits 7.77% variation before crazing is reached, and series III on variation of flint alone, permits 17.7[6]% variation before crazing is reached. The common straight line method of varying one constituent at a time is thus shown to have failed to locate the dangerous composition nearest the standard body.

Only two points (B and D) have been located by Purdy on the boundary between crazed and uninjured glazes. He has done nothing to show whether that boundary is straight or curved, and if curved, what is the degree of curvature.

In series I, variation of china clay, a good deal of unnecessary work was done; unnecessary partly because nearly duplicated by series III, and partly because in a region where the feldspar content is the principal factor in determining whether crazing or shivering will take place, the feldspar is nearly constant in percentage

throughout the series. With a higher feldspar, content the ratio of clays to flint will determine the limit of crazing.

If the twenty-six tests of series I, II and III had been so widely distributed as to differ by 10% intervals, a greater range could have been covered, the boundary between crazing and uninjured glazes more sharply determined, and possibly shivering located. Such a series of body tests of general application to all glazes, would be:

Clays	30	30	30	30	30	30	30	30	40	40	40	40
Flint	70	60	50	40	30	20	10	0	60	50	40	30
Spar	0	10	20	30	40	50	60	70	0	10	20	30

Clays	40	40	40	50	50	50	50	50	50	60	60	60	60
Flint	20	10	0	50	40	30	20	10	0	40	30	20	10
Spar	40	50	60	0	10	20	30	40	50	0	10	20	30

Clays	60	70	70	70	70	80	80	80	90	90	100	36
Flint	0	30	20	10	0	20	10	0	10	0	0	
Spar	40	0	10	20	30	0	10	20	0	10	0	

Let me repeat that though these tests are three times as far apart as Purdy's, they will determine more points on a boundary more accurately than will an equal number of tests by the common series, radiating from a point in two or three lines, varying one element on each line.

It is not really necessary to use a triaxial diagram to show the results. An ordinary diagram, with flint represented by distances to the right (abcissae) and feldspar by vertical distances (ordinates) will show the same thing. The only drawback is that you are likely to forget about the clay, and talk only of flint and spar. The triaxial diagram emphasizes and exhibits the simultaneous variation of three constituents at a time. Paper properly ruled for these diagrams may be obtained from the Journal of Physical Chemistry, Ithaca, New York.

In series I, II and III, the fluctuations of the ratio of ball clay to kaolin have probably not been so great as seriously to affect the diagram, still series IV shows that when carried to extremes the effect is considerable, and

must not be neglected. The two tests of series IV that crazed are porcelain-like in structure, with high shrinkage, while all the other tests of the four series are porous whiteware bodies of moderate shrinkage. Consequently, the crazing in series IV does not affect the accuracy of the diagram as applied to whiteware bodies. Nos. 6521 and 6522 are also porcelains, but preceded by whiteware that crazed, so not affecting accuracy of diagram.

Note. March 13, 1905. Body 6516 has developed one craze line three-eighths inch long. This lies on the line ABHDE of the diagram, indicating that this line is truly the boundary between crazing and uninjured glazes.

GENERAL CONSIDERATION OF FLOOR TILE BODIES MADE FROM CLAY.*

BY

ROSS C. PURDY, Columbus, Ohio.

The manufacture of floor tiles has had its place in the arts of all periods of civilization. Their manufacture and use, like that of other ceramic products, has risen and fallen with civilization in the past, and in our present rapidly developing times their use is becoming more and more extended. Naturally, therefore, the tile body has passed through changes in composition from time to time. In fact, nearly every conceivable silicate product, capable of being formed into tile, such as glass, cement and clay, are today in competition on the market. Of each kind of silicate floor tile there are various characteristic products, so that at this time we can attempt to describe but a small portion of the floor tile bodies in vogue. It will be the aim, therefore, to describe only those bodies used and experimented upon by the writer.

Classification of Clay Floor Tile Bodies.

The design and use of the tile must necessarily form the basis of a classification of the bodies. For our purpose the following presents itself as being the most comprehensive:

Face Tile	vitreous	white colored	Prepared facing body on a common clay backing.
	porous	clay colors	
Tesserae	vitreous	white colored	solid bodies formed into geometric shapes.
	encaustic	clay colors	

* The bulk of the experimental work described in this article was made in the laboratory of Mr. K. Langenbeck, under his direction and general supervision. To him I wish to thus publicly express my appreciation and thanks for his permission to publish the facts at this time and through the Proceedings of the A. C. S.

Face Tiles.

Plain or the Alhambra 6″x 6″ tile, strips of various sizes such as 6″x 3″, 6″x 1½″, etc., used as border tile, are most generally made with a prepared facing body, backed by a more common body.

Backing Body: The facings shortly to be described were pressed into a backing composed of fire clays, ground in a dry-pan to a 16 mesh powder, dampened to the desired amount, and stored in bins for the purpose of distributing the moisture throughout the body.

The policy of using such a comparatively coarse body, and especially one whose chemical and physical properties differ so widely from that of the facing, is questionable. On this point the writer has had no experience, but it seems rational that it would be factory economy to simplify the problem of fitting a vitreous facing onto another body by using, as a backing, a body which corresponds more closely in chemical and physical properties to that of the facing mixtures.

The fitting of a dry pressed vitreous facing onto a comparatively coarse backing is a problem that, while not exactly parallel with the problem of fitting an engobe onto a brick, does call for a consideration of similar principles. An exact control of the plasticity, shrinking and crazing is necessary.

To this end, for different backing clays and different processes of manufacture, different facing mixtures must be used. Therefore, specific formulæ, as is the case with engobes, would be of no value. A general description of their chemical and physical requirements is however, of importance.

In the making of plain facing tiles, i. e., tiles of single or solid color, the face of the die is covered to the required thickness with the prepared facing body. The die is then filled with the backing clay, and the whole pressed into a solid tile. In the making of inlaid tile, which, in this country, are at present confined to the 6″x6″ size, a brass 'cell frame' of the same depth as it is desired to have the fac-

ing mixture, is fitted into the die. Then a sieve, so perforated as to expose only certain cells, is set into the die, and the exposed cells filled with a facing mixture of the desired color. The use of as many sieves as there are colors to be employed in the design, each exposing only that set of cells corresponding in position to that of a certain color, makes possible the reproduction on the face of the tile of any figure desired. The cell frame is then lifted out, tapping it gently meanwhile, and the die filled with the backing clay and the whole pressed into a solid tile. It is obvious from this, that the constancy of the physical properties of the various facing mixtures must be under absolute control.

Clays used in Vitreous Facing Mixtures. No matter what clay or mixture of clays was used for backing, it was found that sufficient ball clay must be used in the facing mixture to insure adhesion of the two bodies. Whether, in the facing mixture, the clay used was all ball clay or a mixture of ball clay and china clay, was dependent upon the physical properties to be developed.

Fluxes Used in Vitreous Facing Mixtures: It cannot be doubted that feldspar, under certain conditions, can be used as a flux in a vitreous facing mixture, but, in all the many experiments designed to exploit its possible use in this connection, not once did it prove successful, while on the other hand it was found possible to use Cornwall stone with unvarying success.

This fact naturally caused considerable surprise, for we had been led to believe that if clay substance, feldspar and flint were compounded in the proper proportions, the mixture would be equivalent in action to Cornwall stone. Prof. Binns[1] states that a mixture of 34 parts of feldspar, 31 parts of china clay and 35 parts of flint is equivalent to 100 parts of Cornwall stone. H. R. Griffin[2] says that 4 parts of feldspar, 1 part of clay, and 1 part of flint is equal to 6 parts of Cornwall stone. Mr. Langenbeck[3]

[1] Ceramic Technology, p. 8.

[2] Clay Glazes and Enamel, p. 36.

[3] Chemistry of Pottery, p. 114.

writes that, "while Cornish stone has distinct uses determined by its physical properties, it could, in the vast majority of cases of its application in the United States, be more cheaply and safely substituted by equivalent amounts of native feldspar, kaolin and quartz, which run more uniform in quality."

Mr. Langenbeck[1] has given the ultimate and rational analysis of typical samples of Cornwall stone, which show two important factors which have not been considered in the above valuations:

1st. In the ultimate analysis of the portion soluble in sulphuric acid, there is found a large percent of alkali, indicating that the "clay substance" consists in the main of mica.

2nd. That in one sample,[2] "the sum of the alkali and combined water in this clay substance falls far short of what would be demanded by a mixture of mica and pure clay, while on subtracting the excess of silica, assuming it as uncombined but soluble in sodium carbonate solution, and recalculating the residue on a percentage basis, they assume the proper proportion. This would make the analysis read:

Clay substance and mica	25.71%
Feldspar	40.68%
Quartz	15.16%
Soluble silica	18.74%
Total	100.31%

The writer's experience corroborates Mr. Langenbeck when he says that direct determination failed to yield any such percentage amount of soluble silica in Cornwall stone, but the excessive silica taken into solution by the sulphuric acid and sodium carbonate treatment proves that the silica is there in some form other than quartz. If it is combined, forming a highly acid silicate, which we know is a possibility, we have a condition not duplicable by a mix-

[1] Chemistry of Pottery, p. 110.

[2] Ibid, p. 113.

ture of feldspar, clay and quartz; if it is there as free silica, we have a peculiar form of silica which is soluble in sulphuric acid and sodium carbonate treatment, but insoluble in the sodium carbonate treatment alone.

In whatever form the silica may be present, we have in Cornwall stone, a large amount of mineral matter, presumedly mica, with its own peculiar behavior as a flux,[1] together with a large quantity of silica, and its peculiar behavior in a body.[2] Does not this evidence show that it is folly, especially in vitrified clay bodies, to reckon a mixture of clay, feldspar and flint equivalent in effect to Cornwall stone? Experience cited in the case of the vitreous facing tile, would indicate that such are the facts.

The writer's experience with the use of feldspar as a flux in bodies, warrants the statement that the case will be most peculiar where a mixture of feldspar, clay and flint can be made to lie without warping, cracking or crazing, when used as a vitreous facing on a backing mixture of a radically different composition and preparation. This same contrast was made evident even in white ware bodies which were not vitrified. Those bodies in which Cornwall stone was the sole or principal fluxing agent, other conditions being favorable, came the nearest to making ware would justify an assurance of being non-crazing.

Samples of granite from New England quarries behaved as fluxes in vitreous facing bodies in every respect like Cornwall stone. The question naturally arises, then, as to why the mixture of igneous minerals could be successfully used where feldspar failed? Experimental data, making possible an answer to this query, is not at hand, but we have supposed that the vital factor lies in the fluxing effect of minerals like mica, hornblende, etc.

The chemical formula of Cornwall stone, calculated from an average of several analyses, was found not to be as that given in our Manual of Ceramic Calculations, but rather:

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[1] Trans. A. C. S. Vol. V, pp. 362, and Vol. II, p. 98.

[2] Trans. A. C. S. Vol. III, p. 25.

$$\left.\begin{array}{l}0.33\ CaO\\0.05\ MgO\\0.62\ KNaO\end{array}\right\}1.34\ Al_2O_3\left\{9.7\ SiO_2\right.$$

whose combining weight, in round numbers, is 805.

All the other fluxes tried, proved unsuccessful in these vitreous facing mixtures. While talc and mineral wool make it easier to keep the shrinkage of the facing down to the limit required by the backing clay we are using, they made adhesion of the facing to the backing very difficult.

Flint used in the Vitreous Facing Mixtures. Whether or not flint should be used in vitreous facings, is dependent wholly upon the relative physical properties of the facing and backing bodies. In most cases, however, it was found that flint can be best added by means of a sandy clay.

Formula of a Vitreous Facing. The formula we found to work best under our conditions, as cone 7, was:

Cornwall stone	60%
Ball clay	25%
Sandy clay	15%

Porous Facing Bodies.

These are composed of buff and red burning clays or a mixture of these clays which will fit, as facings, the backing used, and which will become, on burning, quite dense without destroying their natural colors. They cannot be vitrified without blue-stoning the buffs and rendering the red clays very dark, but this does not affect their use in floors to a very large extent.

A discussion of the chemical behavior of these bodies on vitrification, and of the colors based upon natural clay bodies, will be best deferred until we have considered colors.

Tesserae.

Generally, in tesserae, the body is solid, i. e., made entirely from one body mixture. Sometimes the 2 and 3 inch tesserae are inlaid with a small design, but the inlaid body is not used in sufficient amounts to affect the physical behavior of the main body of the tile. Our problem in mak-

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ing tesserae bodies is simply the manufacture of as serviceable and beautiful a tile as possible, shrinkage and warping not requiring such particular attention as in the case of the face tiles.

Vitreous Tesserae: Vitreous tesserae are porcelains, so compounded as to develop the greatest toughness or resistance to wear under feet that is consistent with the texture of the body and brilliancy of colors demanded by the trade. There are many factors influencing these qualities of the tile, the principal ones being: First, chemical composition of the body; second, physical and chemical character of the clay used; third, the character of the flux employed; fourth, the heat treatment given, and fifth, the process of manufacture.

Concerning these factors we have considerable empirical data. For instance, if we take two bodies having the same percentage composition of feldspar and clay, the clay in the one being non-plastic kaolin, and the clay in the other being the plastic ball clay, we know that the one containing kaolin will vitrify to a more brittle white translucent body, and have a greater shrinkage than the ball clay body. The ball clay body will be stony in fracture, and of a blue cast. We also know that those bodies requiring higher heat for vitrification develop to a larger degree translucency and toughness, and have a wider range between vitrification and incipient fusion. We know also that the more thoroughly and intimately the body ingredients are ground, the more translucent will be the body, etc., etc.

Scientific data concerning the production and control of the physical properties of porcelain, while at present meagre, are being slowly collected. Dr. Cushman's paper on the colloid theory of plasticity, in which he showed the physical difference between the plastic and non-plastic clay substance, and the work of Dr. Edward Berdel, of the Royal Porcelain Works, Berlin, an account of which has been published in the "Sprechsaal" for the year 1904, and several minor contributions, shed light upon this subject which is sure to be productive of great results. We

cannot, however, from data at hand, deduce any definite laws, or lay down any exact principles, but we are able to state general facts governing the production of tesserae.

To obtain the toughness of body, and degree of translucency, and uniformity of shade required in floor tiles, it has been found that a mixture of ball clay and china clay fluxed with feldspar so as to vitrify at from cone 10 to 12 is necessary. Many argue against the use of so high a temperature, but factory results have shown that if the porcelain is burned at a lower heat, say cone 8 or less, greater loss in ware and a greater variety of shades are bound to be the result. The kiln is the poorest place in the factory to practice economy.

Flint. It is often stated by empirical experimenters that flint in a porcelain does not enter into combination, nor in any way affect the fusibility of the mixture. But that such is not the case, at least at the higher heats, has often been proven. The fluxing action of flint on pure kaolin[1] at cone 26-36 is well known; Seger's[2] work showing the effect of an increase in flint from 2 to 5 molecules in cone 4 is classic. The solution of quartz in feldspar, and the effect of the solution in a porcelain body, has been shown by Buenzli[3] and Seger. And finally the question which interests us at this particular place, i. e., "Is the addition of flint to the porcelain body justifiable?" has been debated by Buenzli.[4] He states that for Bohemian porcelain the addition of flint in moderate amounts was not only justifiable, but necessary, for, if only feldspar to the amount of 50 to 75% be added to the kaolin, we would obtain moderately to very fusible spar masses of dry biscuit surfaces, having a yellowish appearance; at the same time, the disagreeable qualities of warping, etc., would make themselves very much felt. But now, if quartz be added, the body would be more stable in the fire, less dry in the biscuit, and of a bluish white color and more translucent.

[1] Seger's Collected Writings, Vol. I, p. 545.

[2] Seger's Collected Writings, Vol. I, p. 237.

[3] Seger's Collected Writings, Vol. I, p. 507.

[4] Seger's Collected Writings, Vol. I, p. 67.

Conclusions on Composition of Vitreous Tesserae Bodies.

Records showing the fluxing action of feldspar, flint and whiting, under conditions different from those of tile manufacture, are very valuable aids in planning empirical experiments and interpreting their results. For vitreous tesserae, 37% ball clay and 63% feldspar, at cone 8 or 9, produced a body that was hard, but lacked the gloss or sheen desired. According to Buenzli and Seger, if flint should be added to this body we would obtain gloss and easier vitrification, but would not the body be made too brittle? Watts says that an addition of lime to the body would toughen it, therefore the conclusion is perhaps justifiable that the body containing flint and whiting in addition to the feldspar and ball clay, would give us a better body for our purpose.

Fluxes in Vitreous Tesserae.

Whiting. The policy of adding whiting to vitreous tessera bodies has been a much mooted question. On this point we have no experimental idea. Watts concluded from his work on porcelains "that with K_2O as the RO, even with a moderately high clay substance, we obtain a brittle and weak porcelain. When as low as 20% of K_2O is replaced by CaO, we find the product changed to a tough but well vitrified body."

Granite Rock. Granite debris accumulates about the New England quarries in large quantities and, at present, is being used principally as a road material. We obtained samples of granite chips from the R. C. Bower Granite Co., Montpelier, Vermont, and the Maine Red Granite Company, Red Beach, Maine.

It is regretted that neither the chemical nor mineralogical composition of the granites experimented upon are known, but in as much as they were all similar in their fluxing action, notwithstanding the fact that they represented different quarries in different states, the results are deemed noteworthy in this place.

Mention has already been made of the fact that the fluxing action of these granites was similar to that of

Cornwall stone, although in some cases the granites were found to be more fusible than feldspar.

Due to the ferruginous minerals they contained, the effect in the vitreous bodies varied according to the fineness of grinding, from a speckle or mottle down to a solid color. The colors were those obtainable from iron, ranging from a dark gray to a vitreous buff. The vitreous buff, however, was not a clear color, due to the black specks thought to be magnetic iron. Proof is not at hand, but it is believed that where the iron in the granite was combined as a silicate, a buff color was the result, but if free, especially in the form of magnetic oxide, a black color resulted.

The amount of iron in the granite, of course, limits the amount of this flux that can be employed. In some cases we have been able to use as high as 50% of granite.

Porphyry and Basalt. The fluxing effect of porphyry and basalt were found to be equal to that of feldspar, but the dark colors resulting in vitreous tessera, even from a small percentage amount, would prohibit their use.

Slags. Slags of various basicity were tried as fluxes, but none proved to be of any value except in the form of mineral wool. We used a mineral wool from the Western Mineral Wool Company, the average analysis of which was:

Silica	38.77 per cent.
Alumina	11.41 per cent.
Ferric Oxide	0.73 per cent.
Lime	40.62 per cent.
Magnesia	3.93 per cent.
Alkalies	1.34 per cent.
Sulphur	0.74 per cent.

Chemical Formula.

$$\left.\begin{array}{l} 0.84\ CaO \\ 0.13\ MgO \\ 0.03\ KNaO \end{array}\right\} 0.13\ Al_2O_3 \left\{ 0.72\ SiO_2 \right.$$

Comb. wt.=111.

In vitreous facings, 5% of mineral wool so decreased the shrinkage as to counteract the tendency that the tile had to "dish." If more than 5% of mineral wool was added the tile would invariably "bow."

In vitreous tesserae, on the other hand, it did not prove to be of any value. Inasmuch as mineral wool is a flux containing considerable lime, and having the property of decreasing shrinkage, it was hoped that it could be used in making vitreous buff clays without the usual attending "bluestoning." Results of many trials along this line, however, proved that mineral wool was not an available flux for this purpose.

Talc. The sample of talc used in our experiments was of the white variety, being a hydrous silicate of magnesia, containing theoretically 62.8% SiO_2 and 33.5% MgO. The results of our experiments are, briefly, as follows:

1st. They did not indicate that vitrification of either a shale, fireclay or porcelain body could be obtained at lower temperatures, or that the range of vitrification was materially widened by the use of talc.

2nd. Talc so counteracted the shrinkage of the facing, vitreous bodies at cone 7 as to cause the tile to "bow." In vitreous tessera bodies at cone 8 to 9, this same phenomena of counteracting shrinkage was noted.

3rd. In the vitreous tessera bodies, talc imparted a dirty appearing stain.

4th. It made pressing very difficult owing to the tendency of the tile to split.

5th. In no case was its use as a flux found justifiable.

Hydromica-Schist. A sample of what was supposed to be a soapstone analyzed as follows:

Silica	48.78
Alumina	33.26
Ferric Oxide	4.37
Lime	1.00
Magnesia	0.43
Alkali	8.80
Volatile	3.98

It was greasy to the touch, pale green in tint, and laminated similarly to mica.

Its behavior in bodies was in general, the same as that of talc. The one important fact to be noted in this connection was that in white vitreous tessera bodies, this schist imparted to the body a very good cream tint, and for this purpose might prove to be of very great value.

Zinc Oxide. There are white, vitreous, floor tiles that have a decided sheen or incipient gloss, a quality very much desired. That this sheen is the result of a peculiar physical condition of the body ingredients, either inherent naturally, or induced by methods of manufacture, was proven by the chemical analysis of tiles showing this phenomenon, and attempts to reproduce them synthetically. To produce this sheen we tried various fluxes, both in the body and as a smear on the surface of the tile. For this purpose zinc oxide was found to be the best, and its used was deemed to be a practical possibility.

Zinc added to the encaustic bodies, behaved most singularly. It fluxed the fireclays to a bluestone very readily, converted the dark buffs, salmons and light reds to shades of seal brown, and made possible the vitrification of Bedford shale, mined at South Park, Ohio, without any deepening in shade. In fact, 5% of zinc gave the shale considerable gloss at cone 6.

The price of zinc oxide prohibits its use, to any great extent, as a body flux, but there are cases where its use is entirely justifiable.

Other Fluxes. Various other fluxes, such as cryolite, fluorspar, glass of various compositions, etc., were tried, but none of them proved to be of any value.

Colors.

The following statement of the production and use of various colors will hold equally true for either facing tile or tesserae. Colors are naturally classified under two headings, viz., vitreous and clay colors, the vitreous colors being those imparted to the vitreous bodies, and the clay colors those which have the naturally colored clays as a base, and are not vitrified.

Vitreous Colors. The most intense and delicate vitreous colors are procurable in those bodies in which all the clay substance is derived from china clay. Why ball clay should, in part, mask the colors, is a mooted question that is not answerable with the data at hand. Further, it is well known that with the majority of colors, vitrification is essential so that the body must be so compounded as to vitrify at the heat to which it is safe to carry the colors, i. e., about cone 6 to 7.

Inasmuch as reliable receipts for the production of body colors are published by several authors, it is not deemed advisable to dwell upon them at this time. The creams, however, will be discussed to some length, because of the side light their production throws upon the cause of bluestoning in buffs, and the darkening in shade of the reds as they approach vitrification.

Creams. For harmony in color schemes, it was desired to have either a vitreous light cream or a blue tint to take the place of the pure vitreous white. It was suggested that the yellow or blue shades of our regular white be used for this purpose, the yellow being underfired and the blue the overfired tile. An absorption test on these shades, as here given, proved the unfeasibility of such a plan.

Absorption Test on White Vitreous Tiles to Show that the Yellow and Blue Shades are Porous.

	Yellow.	White.	Blue.
1	1.778%	0.510%	0.894%
2	2.014%	0.370%	0.859%
3	0.468%	0.050%	1.000%
4	1.780%	0.217%	1.040%
5	0.915%	0.050%	1.650%
6	0.852%	0.221%	1.090%
7	1.310%	0.090%	.....
8	1.364%	0.150%	.....
9	0.160%	0.124%	.....
10	2.850%	0.073%	.....
Average	1.349	0.185	1.09

To produce a stain that would impart a cream tint to a vitreous body was therefore our problem. Yellow underglaze stains were tried, but only those which had iron as a colorant proved promising. Red and buff clays, added to the white, vitreous, in small percentage amounts, caused bluestoning. Raw bauxite gave indifferent results, no two samples imparting the same tint. One sample of ground granite rock gave very promising results, but the experiments were not carried sufficiently far to state whether or not it would be feasible to use granite for this purpose. The sample of hydromica schist, referred to before, gave excellent results, but the exact nature of the mineral and extent of its deposit not being known, we lost interest in continuing this attack of the problem. Certain samples of rutile, when added to a china clay vitreous white gave a most desirable cream, but uniform success could not be obtained with different samples, although they were supposedly from the same deposit.

Having had but indifferent success with the iron bearing minerals, we turned our attention to the making of an iron bearing calcine. The following mixtures were calcined at cone 8 in the form of very fine powders, and used in the vitreous white in amounts ranging from 5 to 15% of the total batch weight.

	5495	5776	5778
Dark red clay (open burning)	10	10	10
Sandy fireclay	80	75	70
Whiting	10	15	20

Notwithstanding the fact that these calcines are very much alike in composition, their effect in the vitreous bodies was quite different. The only good cream tint that was obtained by their use was with 15% of 5495.

The greatest trouble with stains compounded from colored clays, is, that they are too apt to vary in quality from time to time, and would only be of local value. These

clay calcines, however, gave us the clue to the solution of our problem.

We next tried calcines of oxide of iron with other oxides, as follows:

	6049	6050	6051	6052
Oxide of Aluminum.....	95	85	90	85
Ferric Oxide	5	15	5	10
Zinc Oxide	..	..	5	5

In these stains, the iron was added by the precipitation of iron hydroxide, from a solution of ferric chloride of known strength, by means of sodium carbonate, according to the following reaction:

$$Fe_2\,Cl_6 + 3\,Na_2\,CO_3 + 3\,H_2O = Fe_2\,(OH)_6 + 6\,NaCl + 3\,CO_2$$

Commercial solutions of ferric chloride are of various degrees of concentration, but their exact strength per unit of weight can be quite readily determined, or in most cases the firms supplying the solution will give this data. After ascertaining the strength of the solution, the problem is:

1st. To determine how much of the solution is required to give the ferric hydroxide equivalent to the amount of ferric oxide required. 2nd. The amount of carbonate of soda necessary to precipitate this ferric hydroxide.

The oxide of aluminum, or oxide of aluminum and oxide of zinc, were dry blended, roughly, by hand sieving. The required sodium carbonate was dissolved in an excess of hot water, and when in complete solution, the alumina was added and the whole blunged to the consistency of cream. To this slip was added the ferric chloride solution, the whole stirred vigorously until the precipitation of hydroxide of iron was complete. Owing to the fact that the slip was very materially thickened by the precipitated hydroxide, care was taken that sufficient water was present so that the chloride solution could be very readily disseminated throughout the mass. This slip was washed free from salt

by decantation, then dried, powdered, and calcined at cone 6-8.

Trials with the above stains. Stains Nos. 6049, 6050, 6051, and 6052 were added in amounts equal to 1, 2, 5, and 5 percent, by weight, to New Jersey ball clay, a fine grained No. 2 fireclay, a sandy No. 2 fireclay, and a china clay, and burned at various temperatures, but in all cases the coloring effect was lost entirely. Vitreous bodies were then prepared containing 5% by weight of these stains. Stain No. 6049 imparted a beautiful cream tint, but the other stains gave very much darker colors.

Stains similar to 6049-6052 were prepared by grinding together as intimately as possible, the alumina or alumina and zinc with red oxide of iron. These stains were then calcined, as were the others. From their physical appearance, these stains were in every way like those prepared by precipitation. When tried in parallel series, it was found that while those stains made with the red oxide of iron did produce creams, they did not have the coloring power nor produce the richness of tint equal to that produced by those prepared by precipitation.

Oxide of iron was added by the described process of precipitation and calcination to several different bases, such as flint, calcined china clay, etc. The tint imparted by these various stains thus produced, varied somewhat, but otherwise they agreed in their general effect.

Fritts of various compositions bearing iron were tried, but it was found that unless great precaution was taken to thoroughly disseminate these fritts throughout the body, they would, on fusing, form little pools of melted glass, rendering the face of the tile pitted, and the color unevenly distributed. The color imparted, however, was that of a cream.

Conclusion on Experiments to Produce Vitreous Cream Tile, with Iron as a Colorant.

1st. Oxide of iron in a vitreous china clay body, added as such, or as a constituent of clay, causes bluestoning on vitrification.

2nd. Iron in silicate minerals such as granite, schists, talc, etc., when added to the vitreous china clay bodies, do not cause bluestoning on vitrification, but rather imparts to the vitreous bodies the characteristic cream of the iron compound.

3rd. Iron, when intimately mixed with fine flint or alumina and then calcined at cone 8, behaves, on vitrification of the body, as did the iron from the silicate minerals.

4th. Not any of these stains made as strong or as rich a tint in a ball clay body as in the china clay body.

5th. Vitrification of the body was required to develop the coloring effect of iron in all cases.

6th. Iron, precipitated as a hydroxide upon alumina or silica, had greater strength of color, and produced richer tints, than did the admixture of oxide or iron and alumina or flint, by merely grinding them together.

7th. A stain containing 95% of alumina plus 5% of oxide of iron, derived from ferric chloride solution by precipitation, gave the best results as a cream stain.

8th. An increase in intensity of color could not be obtained beyond that of a cream, by any increase in the amount of the 5% iron stain. The tint could be made deeper and more intense only by increasing the amount of iron in the stain.

The fact that iron oxide, previously calcined in contact with silica, or even with alumina, when used in this combination as a body constituent, results in a lighter or more cream color than when an iron carrying clay is used, may be ascribed to several causes. It is quite evident that on heating a small amount of ferric oxide with a large excess of silica or alumina, an acid silicate, or an aluminum-iron compound, high in alumina, is produced, and thus the free ferric oxide is converted into the combined form. Now we know that through all the chemical reactions, the reaction takes place most completely when the substance to be taken up is chemically combined, a fact which we know to apply to many igneous chemical processes such as the formation of hydraulic silicates.

The content of iron in clays is ordinarily represented by two forms, combined and free. No difficulty is experienced in assimilating the combined iron usually present as a constituent of one of the iron bearing minerals, and hence, unless the mineral is very ferruginous and is present in excess, its iron will enter into the vitrified magma of the body with ease, and will result in a uniform cream color, On the other hand, the free iron present in varying grades of fineness is not so easily taken up, and is liable to remain either as the oxide or as a basic silicate, both subject to the action of reducing gases and showing the general tendency to form magnetic oxide of iron when ignited, which is dark in color. That this magnetic oxide is present in burned clay has been shown by numerous recent experiments involving the testing of magnetic phenomena in burned bricks. The more free oxide a clay thus contains, the more liable will it be to show the undesirable dark colors.

The objection might be raised that, if a reaction takes place on heating ferric oxide and silica, the production of a ferric silicate must be assumed, whose existence is denied by some, though the work of Chatelier and others seems to show quite clearly that ferric silicates do exist.

Ignition of iron with an excess of even an inert material will at least result in uniform oxidation to the ferric state. Likewise in such a mixture, containing but a small amount of iron oxide, the contact surface is increased most decidedly, and hence the chemical reaction is made more complete.

Encaustic Tesserae.

With these considerations of the effect of iron when combined and when free, in a vitreous body, we are prepared to take up the study of encaustic tesserae.

Encaustic tesserae have for their base, buff and red burning clays. As is well known, the iron naturally occuring in the buff and red clays is mainly present as free oxide, so that the burning of these tiles to vitrification without destruction of the color is an impossibility. All

attempts to so alter the chemical composition of the buff and red clays, by admixtures of various fluxes so that they could be vitrified and not darken in color, proved futile.

Here are contrasted the analyses of two buff bodies, which have very radical physical differences:

	American	French
Silica	69.26	71.30
Alumina	25.76	23.02
Ferric Oxide	1.54	1.23
Lime	0.83	1.62
Magnesia	0.52	0.31
Alkalies	2.15	2.62
	100.06	100.10

Notwithstanding the fact that these two tiles are similar in chemical composition, they are physically vastly different. The French tile has a very bright, deep yellow, vitreous body, while the American tile has a light yellow, porous body, which will bluestone if made to approach the vitrification shown by the French tile.

Clay Colors. Buffs, salmon, reds, lava, granite, chocolate and blacks are colors usually based upon the so-called natural clay bodies, hence the name clay colors.

Inasmuch as the various shades of buffs, salmons and reds are obtained solely by the use of red and buff burning clays, it will be futile to give formulæ for these colors. The production of lava and granites and gray colors, similar to those produced on face brick, require no special discussion at this place. A few words on the production of chocolate and black, however, are deemed advisable.

In the English receipts for black and chocolate bodies, they use a white clay basis and chromate of iron as a color. After many attempts to produce chocolates and blacks on similar bases, we concluded that they did not give as satisfactory results as did the staining of red clays with manganese. To produce a chocolate and a black, a bright red clay is required. An addition of 0.5% of recovered

manganese to this red clay will produce a beautiful chocolate, and 1½% of recovered manganese will produce a beautiful jet black. The most important point to be noted here is the use of the fine powdered precipitate of manganese. No other form of manganese would serve our purpose in the production of these colors.

In a general paper of this nature the various topics are not treated as thoroughly as possibly they should be, but it is hoped that the vital points involved in the manufacture of floor tile have been presented. Receipts are not given except in so far as they are required as illustrations, but it is hoped that sufficient stress has been laid upon the production of those not usually considered in receipt books, to show the proper methods of attack. The theory of the cause of bluestoning, as given in this paper, is not sufficiently backed up by research to warrant positive statements, but it is hoped that what has been given will call out investigations along this line. It can hardly be hoped that it will be possible to commercially alter a red or buff clay so as to permit their vitrification without the destruction of their color, but the results of such an investigation would aid greatly in determining the value of clays for purposes where a dense body is required.

MATT GLAZES AT HIGH TEMPERATURES.

BY

CHARLES F. BINNS, Alfred, N. Y.

Most of the work hitherto carried out in matt glazes has been at temperatures ranging from cone .04 to 4 or 5, and a casual glance at the subject would seem to indicate that this is all that is necessary. Upon fuller consideration, however, it will be found that there are many and cogent reasons why results should be sought at the higher cones.

Several attempts have been made, especially in Europe, to produce matts upon porcelain, but most of them have the appearance of an after treatment over the regular porcelain glaze, while the remainder seem to owe their texture to an excessive use of titanium oxide.

There is a strong desire on the part of those who cultivate the artistic sense, to secure glazes of silky texture, but without the gloss of the brilliant type. The effect thus sougth is especially desirable upon architectural terra cotta, and at once the problem of weather resistance presents itself. It is manifestly impossible to place a low-fire matt, of the nature used upon faience, over a soft body and expect it to stand frost.

The usual type of terra cotta matts are not really glazes at all but engobes of a more or less vitreous nature. They are sprayed on to the ware in quite a thin coating, and can never develop the egg-shell texture of the true matt. On the contrary they have the defect, though this is by the way, of transforming the interest of the natural variation of clay-wares into a dead uniformity, which is as monotonous as it is false. The porcelain treatment already referred to is an outcome of the same desire, but here again ingenuity is misapplied. But little sympathy can be found here for those who would present a porcelain

which has had the brilliant quality of its glaze sullied and besmirched in the mistaken idea that anything dull is beautiful.

What, then, is a matt glaze? How is it to be used? What is to be gained by high temperature? How is a high-temperature matt to be made? These are the questions presenting themselves for solution.

1. A matt glaze, in the best definition of the word, is a glaze, either white or colored, which covers the ware in thick, unctuous masses, which is not brilliant, but which presents to the touch a quality and texture at once sympathetic and firm. It is not a smear or half-glaze, nor is it a bright glaze deadened by a second coating or by acid or sand-blast.

2. A matt glaze is proper to certain types of pottery. Not to porcelain, for a matt is not necessarily either transparent or translucent. Not to plates and dishes, because the texture surface is not the surface of utility. The proper ware for a matt surface is either faience or gres, and its function is ornamental. Vases for decoration, tile and terra cotta are eminently suitable for matt treatment, and while for the first a low fire will suffice, for the last two a high temperature is essential.

3. This raises the third point or the question as to the gain to be secured by the hish fire. There are several. First, density. In the perfect pottery the glaze is an ornamentation and not a necessary completion of the ware. A pottery which needs a glaze in order to preserve it from damage or disintegration, is imperfect. The function of a glaze, therefore, is to give additional pleasure, either in use or appearance. The ideal pottery is complete, as far as density, strength, and vitrification are concerned, without any glaze. Hence, in a high fire, the ware is more perfect than in a low. A dense body is strong and wears well, it is, moreover, proof against frost, and the glaze does not tend to craze because the body is constant and not subject to continual change. Second, texture. Glazes differ greatly in this quality, not only as their composition varies, but as the heat changes. The differences are not easy

to explain, but perhaps some of the pieces shown here may serve to illustrate it, and every trained ceramist knows that the hard-fire wares have an air of distinction which is indescribable. One can see at a glance, for example, the difference between Chinese hard and soft paste, or between faience and porcelain. Third, color. It may seem to some that the advantage here is all the other way, but it is not so. It is true that there are more metallic colorants available at the low heat, but the character of the hues obtained at the high fire is incomparably more refined and sympathetic. Besides, in compounding high-fire glazes we have the possibility of reducing action, in itself a manifest advantage.

4. To the fourth question the following answer is offered:

Having worked for some years on low-fire matt glazes, there were brougth to my notice a few months ago a number of matt glazes said to be those used at Sevres, on gres. The principal of these were given as follows:

A		B	
Feldspar	26	Feldspar	45
Kaolin	34	Kaolin	11
Sand	24	Sand	11
Chalk	16	Chalk	22
	100	Rutile	8
		Iron Oxide	3
			100

The formulæ of these worked out thus:

A

$$\left.\begin{array}{l} .712\ CaO \\ .288\ K_2O \end{array}\right\} .818\ Al_2O_3, \quad 4.355\ SiO_2$$

B

$$\left.\begin{array}{l} .729\ CaO \\ .271\ K_2O \end{array}\right\} \begin{array}{l} .426\ Al_2O_3 \\ .043\ Fe_2O_3 \end{array} \left\{\begin{array}{l} 2.60\ SiO_2 \\ .343\ TiO_2 \end{array}\right.$$

and the oxygen ratio was 2.5 in A, 2.4 in B.

This was not in accordance with recent practice, and called for investigation.

In matt glazes at cone .03, the oxygen ratio had always ranged from 1.2 to 1.4, and at cone 6 it had not ex-

ceeded 1.6, so that there was no apparent reason why it should run as high as the figures given. However, the glazes were tried and burned at cone 9. The result went far to confirm the suspicion raised, for the glazes failed to develop the true matt quality. They were rather greasy or soapy in appearance. The colors were, however, interesting and promising, so that it seemed worth while to go on.

The formulæ given were boldly disregarded, and two new ones laid down:

No. 1.

$$\left.\begin{array}{l}.3\ K_2O\\.7\ CaO\end{array}\right\}.8\ Al_2O_3,\quad 2.8\ SiO_2$$

O. R. 1.64

No. 2.

$$\left.\begin{array}{l}.3\ K_2O\\.7\ CaO\end{array}\right\}.7\ Al_2O_3,\quad 2.6\ SiO_2$$

O. R. 1.67

It will be observed that the silica content is, in each case, just what will be brought in by feldspar and kaolin without the addition of any flint. Therefore, with the potash standing as it does, it is impossible to bring the oxygen ratio any lower.

The glazes were made up, ground in a ball-mill and dried, and then, to save time, a large number of color trials were made with each glaze. The burn was at cone 9, cone 8 going down inside the saggers.

Some of the results are before you. Glaze No. 1 proved too hard but No. 2 was a satisfactory matt, the texture well developed and the colors good.

It seemed desirable now to determine whether No. 2 was the best composition for the purpose. No. 1 was therefore used as the upper extreme, and the lower extreme was:

No. 25.

$$\left.\begin{array}{l}.3\ K_2O\\.7\ CaO\end{array}\right\}.4\ Al_2O_3,\quad 2.0\ SiO_2$$

O. R. 1.8

Four intermediates were prepared:

No.	K_2O	CaO	Al_2O_3	SiO_2	Ox. Ratio.
26	.3	.7	.72	2.64	1.67
27	.3	.7	.64	2.48	1.69
28	.3	.7	.56	2.32	1.73
29	.3	.7	.48	2.16	1.77

As time began to press, and as firings at cone 9 had to be planned ahead, because this was not the usual temperature of work at the school, glaze No. 27 was chosen as a probably correct mix, and was used for the testing of certain color qualities which it was believed the glaze would afford.

The series 25-29 all proved fairly good matts but were found to craze on the body used. This did not affect the inquiry, but it was observed that the mesh of the crackle was very regular and, moreover, graded in size in opposition to the oxygen ratio. This opened up a further field which is now being explored.

Two more series were then planned:

No.	K_2O	CaO	Al_2O_3	SiO_2	Ox. Ratio.
51	.3	.7	.40	2.20	2.0
52	.3	.7	.46	2.38	2.0
53	.3	.7	.52	2.56	2.0
54	.3	.7	.55	2.65	2.0
55	.3	.7	.58	2.74	2.0
56	.3	.7	.64	2.92	2.0
57	.3	.7	.70	3.10	2.0

the oxygen ratio being kept constant throughout the series, and:

No.	K_2O	CaO	Al_2O_3	SiO_2	Ox. Ratio.
58	.3	.7	.55	2.32	1.75
59	.3	.7	.55	2.58	1.95
60	.3	.7	.55	2.84	2.13
61	.3	.7	.55	2.98	2.24
62	.3	.7	.55	3.11	2.34
63	.3	.7	.55	3.37	2.54
64	.3	.7	.55	3.64	2.75

The former of these series presented no matt at all. The lower numbers were bright, and the higher immature. Neither did the latter series contain a really good matt. No. 60 was the nearest, with O. R. 2.13, but the thick glaze at the bottom shows that the true condition of matt production has not been reached. It is evident that in the former case the oxygen ratio is too high, in the latter the alumina is too low.

It therefore appears that No. 27

.3 K_2O, .7 CaO, .64 Al_2O_3, 2.48 SiO_2, Ox. Ratio 1.69

is the best matt at present found. This is the glaze upon which the second series of colors was founded, and has given the best results.

The work remaining to be done will be in the direction of lowering the oxygen ratio, but as this necessarily involves a change of the basic contents, some time must be taken to work the matter out.

A number of color trials have been brought for inspection. The oxides used are cobalt, chromium, copper, iron, nickel, manganese, uranium, zinc, titanium and tin, with some natural materials such as shale, clay and umber. It was rather a surprise that copper did not volatilize, but it may be that the rapid fire, 24 hours, enabled it to stand, or,

perhaps the matt glaze holds it better than a bright glaze would.

Titanium, in the form of rutile, affords many novel and interesting effects. So far as present observation goes, titanium is not dissolved in or combined with the glaze substance, but merely suspended. It has the effect of stimulating crystallization, and therefore helps the matt surface, at the same time the texture of a titanium matt is scarcely so tender as that of one founded on alumina. The reason for this relative coarseness of surface is that the crystals induced by titanium are larger than the others.

The range of colors and variety here shown affords strong evidence of the interest attaching to high-fire matts, and there does not seem to be any reason why we should not produce with them artistic stoneware which would rival any in the world.

DISCUSSION.

Mr. Stover: I would like to ask Professor Binns whether his alumina in all cases came in through the feldspar or clay?

Mr. Binns: Both.

Mr. Stover: Did you make trials by using the commercial oxide of alumina?

Mr. Binns: No.

Mr. Stover: You have made no experiments using that at the expense of clay? I had seen some and wondered whether yours gave the same results.

Mr. Binns:—What was the result of the experiments?

Mr. Stover: It was said that the substitution made a smoother and better looking matt.

Mr. Binns: I doubt whether it would.

Mr. Stover: If the person who showed me his samples was telling the real facts, it certainly did.

Mr. Geijsbeek: I would like to ask Professor Binns why he chose cone nine for his burning temperature? The regular stoneware manufacturer never goes higher than eight. I would like to know why he chose one cone higher than that used for practical work.

Mr. Binns: Because that is the temperature given for French gres ware. Glaze No. 29 would mature at cone eight, as would No. 25.

COEFFICIENT EQUIVALENTS.

BY

STANLEY G. BURT, Cincinnati, Ohio.

Volumes could be written on the subject of crazing, as each point considered involves so many factors. Crazing is a question of the two coefficients—that of the body and of the glaze. Let us consider the body. Our pottery bodies are made up of four ingredients—spar, kaolin, ball clay and flint, giving merely a general consideration and leaving out such unusual additions as bone, lime or other constituents. Now each of our four ingredients has its own coefficient, and I name them as these coefficients vary from low to high—that is, spar is our lowest, followed closely by kaolin, then ball clay followed by flint, with a much higher coefficient even than the ball. We have made splendid progress on the chemical side of our art with our equivalent weights and our rational analysis, but what has been accomplished on the physical side to help us with determining plasticity, this problem of coefficiency that we are here dealing with, and many others? Of actual scientific value, in the sense of facts accurately determined and fixed, some work has been done on this coefficient problem by European scientists, who have determined numerically the coefficients of many pottery ingredients. This information, to my knowledge, has not as yet been put into workable form for the lay mind. So we are still privileged, in a crude way, to obtain if possible, theories or devices which will help us to obtain results. What are these results which we desire? They are products which show neither crazing nor shivering. That is, bodies and glazes whose coefficients of expansion and contraction are the same. Now is it possible to give a theoretical numerical value of these coefficients? We know they have absolute numerical values, which by the aid of science, we hope some day to get, but can we not, meanwhile, from the results our daily practice has shown, form an approximate

or at least a serviceable estimation of what these coefficients are?

Our society will always have problems appealing first to those of us, of whom I am one, who are manufacturing, and must have results whatever science may say, and those of us to whom science is supreme. In time we are bound to agree, though now, when a problem comes up, the scientific explanation first offered often does not agree with the results obtained. What I am pleading for is your gentle treatment of the crude suggestion I am about to offer you, and to acknowledge how cheerfully I will drop it when tardy science furnishes the perfect instrument for our use.

What I wish to offer is some arbitrary coefficient units. Starting again with our body I would call spar—1, kaolin—2, ball clay—4, and flint—10. That is, kaolin has twice as big a coefficient as spar; ball clay four times, and flint ten times. Now if I am using a body made up, let us say, of 40 kaolin, 20 ball clay, 15 spar, and 25 flint, we would have the 15 spar—15; 40 kaolin—80; 20 ball clay—80, and 25 flint—25, giving a total of 245. So we could easily and at once get at a comparative value of any body.

Leaving our coefficient equivalent for a moment, let us consider whether we can form a satisfactory mental conception of the physical reactions in a body. Let us consider that we have particles of our four ingredients—spar, kaolin, ball clay and flint—mixed together. As we begin to heat them all expand, at the same time the clay is losing its water mechanically and chemically combined, undergoing a shrinkage which allows of our various particles drawing closer together. Now each of our four ingredients expands with its own coefficient. If we consider this expansion taking place in an open porous body, much of it may be considered taken up by the particles expanding into the vacant pores, so that the mass, as a whole, shows but a slight increase, but as the heat advances, the spar fuses, it draws the other ingredients into fusion, our pores become more and more filled, and the body, as a

whole, becomes more firmer and more a unit. In this state the expansion of the whole is greater. If we press an open soft sponge, this pressure may be entirely absorbed by the closing of its pores and not be felt on the opposite side, but take a fully compressed sponge, we have a unit transmitting any pressure throughout. This is not an exactly similar case, but will serve to convey my idea. So we see why an underfired body crazes. Its coefficient is very low, due to the extreme porosity of the body, neutralizing the high coefficient of the silica present, but the harder fired body, being harder and more a unit, has the greater coefficient.

We now come to the consideration why it is that silica should have so high a coefficient, and spar and kaolin one so low. Scientific research has proven that crystalline silica has a high coefficient and that the amorphous silica has a low value. Those of us who saw the remarkable demonstrations at the St. Louis Exposition with silica glass are pretty well convinced of the low coefficient of amorphous silica. This silica glass is formed by the fusion, at an intense heat, of pure silica. The resultant glass has so low a coefficient, that when heated to a high red heat it may be plunged into ice water without hurting the glass. Now when the crystalline silica enters into a silicate formation, it sacrifices its high coefficient and partakes much more of the low amorphous type. We know the queer changes in melting points brought about by fusing elements together, and it would seem that some such change was caused in coefficients, for when nature fused Na_2O, Al_2O_3 and SiO_2 together, and gave us spar, the resultant coefficient was probably lower than the original coefficient of any of the three, excepting amorphous silica. So we seem justified in assuming that in silicate formations the silica coefficient will be that of the amorphous silica. The spar, as a silicate, we consider our lowest body ingredient, and call it 1. Now the kaolin is also a silicate and might, if absolutely pure, rank very close to the spar, but it invariably has a greater or less percentage of free silica present, and as in this general consideration we can only deal with average samples, I rank it as 2, to the 1 of spar. The ball

clay, while also a silicate, owes its greater coefficient to three causes: First, it carries a greater percentage of free silica, second, as it is a sedimentary clay, I consider that by its water carriage its particles have become much more finely ground, thus allowing closer union of the particles and a greater coefficient as before explained, and third, as it always carries more or less fluxing impurities, these will also tend to bring about closer union when fired. So I give ball clay a value of 4.

Now a few practical aspects of the body problem. Suppose you have crazing, we know the body coefficient is too low, so we turn to our scale and see at once the great gain by replacing other ingredients with silica. Practice shows that this is what is ordinarily done, up to a limit, especially as the silica can often be had cheaper than the fine white clay, and gives a whiter body. However, there is a limit, for we soon find our body so short that the ware cracks so badly that the body is worthless. So we try more ball clay, but this affects the color of the body, and if carried the least bit too far will in turn give us cracked ware, and out of shape at that. Kaolin is also short, and then it is too close in spar in its coefficient to help much. We soon see that with the body the practical variations are very limited.

When we realize the body limitations we will understand that, given a satisfactory body as far as working with it goes, it will be far better to correct crazing and shivering by changing the glaze than to risk changing the body.

Taking up the craze question, that is, the coefficient question, of glazes, we first arrange our scale just as we did for the body. This will read from low to high, flint, stone, spar, kaolin, calcium, zinc and lead. Before attempting to give the coefficient values let us consider this scale briefly. It contains the apparently striking contradiction of which I have spoken to the society before. I well remember my surprise on first discovering it. The point is, that while the body scale ranks silica as the highest, here in our glaze scale it ranks lowest as to the coefficient.

I have already explained this contradiction when speaking about body coefficients, for as shown there, silica in silicate formations takes the lowest coefficient, that of the amorphous, and not the high one of the crystalline silica. Of course, we consider all glazes as completed silicates, although I may have occasion to speak of an interesting case where I have doubts on this point. So much for the glaze silica coefficient. The Cornish stone I rank next to silica on account of the high percent of silica which it carries. The spar and kaolin both have a low coefficient as in the body. Now taking the bases, I think it is Seger who ranks them from low to high coefficient, just as their atomic weights advance from low to high. I have followed this in the main as my experience agrees with it, and I think we will all agree that Pb heads the list for the high. You will note that I have omitted from my glaze scale boric acid. I will speak of this later as I am here treating of raw glazes, that is, those which do not need to be fritted.

Now there has been considerable scientific investigation of the coefficients of glasses, how the increase of various ingredients affects the coefficients, but I have been guided by such of this research as I have seen, only in so far as it has agreed with my actual results. I feel that we have a considerable delay ahead of us before science can give us exact figures, if it ever will be able to do so, for let us consider what is involved in arriving at these values for our body ingredients alone. Take for instance spar. Is it sodium, potassium or lime spar? What is its exact chemical analysis and the coefficient corresponding to each analysis? Then think how complex the question becomes when we begin to consider the glaze. The mass of investigation necessary is appalling, and when this has all been done, if it ever will be, what can the potter do then but to attempt to draw general conclusions applicable to his own peculiar case?

So I doubt very much whether the average potter will ever know the absolute scientific values of his body or glaze. Just as we know a potter's formula is worthless

for other ingredients or conditions, so certain coefficients will have to be determined by the individual potter for himself.

So I am merely offering you arbitrary figures, based mainly on my own practical experience, trusting they may be of assistance to others as they have been to me. This being clearly understood, I would number my glaze scale as follows: Silica 1, Cornish stone 2, spar 3, kaolin 3, calcium 6, zinc 7, lead 10.

In a glaze we have this radical difference from a body, in that we have no question about loss of expansion as a whole through porosity of mass. The glaze is, of course, a unit. Why then, you ask, does an underfired glaze craze while a fuller fire may make it perfect? This we answer by saying that under fuller fire it takes up silica from the body and thus reduces its coefficient. It has always struck me that if we are taking up silica from the body and reducing the glaze coefficient, why are we not at the same time reducing the body coefficient. 'Tis true, but only a small percent of the body is affected, and the glaze coefficient meets the body coefficient as a whole, and not that of its surface. This is very well illustrated in applied slip work. Thin slip applied to a body makes no noticeable difference, but as you apply it heavier you presently reach a point at which the glaze feels the coefficient of the slip, and not that of the body.

I have already mentioned the European work on this subject and there may be other research, but I have seen no sign of any one advancing a simple little scale such as I am giving you and vouching for having tested it practically. Furthermore, it is rather hard to explain, and hard for one new to it to grasp this coefficient question. This scale device I have found of the greatest value.

You will note that the body I gave you as an example was reduced to a percentage basis. This should always be done before attempting to use the scale both for body and glaze. Where the rational analysis is available the free silica shown by it should be transferred to silica, but I still reckon the clay substance found in the kaolin as 2

and that in the ball clay as 4, owing as was explained, to the finer grain and the fluxes in the ball. Furthermore, I work with a standard lawn. It is of no use attempting to estimate what your results will be if your body is coarse at one time and fine at another. Moreover, naturally, all ingredients are assumed to be bone dry and organic matter in the ball clay must be allowed for. I also assume if I happen to be using any grog in my mixtures, that the coefficient of its original ingredient may be taken and any possible change due to its being fired may be neglected. If coarser grog than the standard lawn is used, it may prove a disturbing factor.

Let me now give an example of the use of these equivalents. Taking the body given before and assuming that the SiO_2 shown by the rational analysis has been properly allowed for, we will have

	Body A	Body B	Body C
Kaolin	40× 2= 80	35× 2= 70	25× 2= 50
Ball Clay..	20× 4= 80	25× 4=100	25× 4=100
Spar	15× 1= 15	10× 1= 10	10× 1= 10
Flint	25×10=250	30×10=300	40×10=400
	425	480	560

	Glaze A	Glaze B
PbO	40×10=400	30×10=300
ZnO	6× 7= 42	6× 7= 42
CaO	10× 6= 60	10× 6= 60
Kaolin	8× 3= 24	8× 3= 24
Spar	6× 3= 18	.....
Stone	10× 2= 20	16× 2= 32
Silica	20× 1= 20	30× 1= 30
	584	488

That is a total for body A of 425 equivalents. Let us now assume a glaze as follows: Glaze A, we find has a

coefficient of 584—that is, 159 equivalents greater than that of the body. This will never do, for we are just about certain to have crazing, so we must either raise the coefficient of the body or lower that of the glaze. Let us try lowering the glaze, using glaze B. This reduces our glaze nearly 100 equiv. but is still pretty far off from the body, so let us try raising the body coefficient namely, body B. Here we have glaze B and body B very close, and should have freedom from crazing or shivering. Suppose, for example, we try a still further change of body, namely, body C, and try glaze B on it. We now see that the body coefficient is much greater than that of the glaze, and shivering would very probably result.

To those familiar with Seger's laws, their demonstration will be made more clear by means of these figures. Let us take an imaginary body, namely body X, and note, for example, what a great change replacing spar by flint gives. In my own practice I have known 3%, whether taken as spar or flint, to make all the difference between crazing and freedom from it.

	Body X	Body Y	Body Z
Kaolin	25— 50	25— 50	25— 50
Ball Clay	25—100	25—100	25—100
Spar	25— 25	20— 20	15— 15
Flint	25—250	30—300	35—350
	425	470	425

In the same manner which I have shown in bodies X, Y and Z, the increase of our coefficient by increasing flint at the expense of spar, and Seger's other rules may be demonstrated. The same is true for the rules covering glazes, except in one point, concerning which I shall now speak.

Now it would be absurd to claim that any such simple device would prove a cure-all for crazing. All I can claim for it is that it is an aid to understanding part of this complex problem. We know that each additional

degree of fire changes all coefficients, that the slightest chemical or physical variation of each ingredient varies its coefficient, that even with the same fire, a rapid or a slow cooling may again change matters and so on, for there are many factors at work. Furthermore, these figures that I give, which have proved of service to me, may not serve another, but he should, with his results before him, soon see what changes may be necessary.

While I have stated that I have been guided mainly by practical results obtained, and not by scientific theory, I am free to confess I should have offered this paper to the society some years ago, were it not for the fact that while for unfritted glazes my scale worked with such satisfactory results, when B_2O_3 was introduced and the glaze fritted, this scale and what scientific theory I could get, seemed at fault. All B_2O_3 fritted glazes I have figured, if we take B_2O_3 as Seger would have us do, as low as silica (he in fact places it lower) and call it 1, give a glaze coefficient often 100 and more equivalents below that of the body and instead of shivering badly, as they should, are on the contrary, very apt to craze. Scientific examination of glass on adding increased quantities of boric acid, shows that while the coefficient is at first reduced, it presently reaches a minimum and then proceeds to increase. But this does not help us, as the quantities used by potters, according to this, will merely serve to decrease it. Then comes the question of whether a fritted glaze, or a raw one, will more readily take up silica from the body. All theory works contrary to results, and yet through it all our body scale is unaffected, and taking a uniform fritted glaze and merely working with the body scale, we can arrive at crazing or shivering just as we do for a raw glaze. I am free to confess that I have been unable to form any theory to cover this phenomenon, and as I have said, I hesitated about offering any of this to the society as long as this bad discrepancy remained, but realizing that others might benefit as I had, where my theory did work, and that a general discussion was the best means of arriving at

an explanation of the contradiction I have given you, I was persuaded to give you what I have.

In closing, let me say, when the idea of such a scale first came to me some years ago, I tested it at once in the comparatively crude way I have given you, and in a short time I was obtaining satisfactory results. My solution of the boric acid problem which was, however, diametrically opposed to Seger and others, was to give it a value of 10. As I obtained results by these means I have never taken the time to make, as should be done, a careful estimation of whether a scale could not be devised using the chemical formula as a base.

NOTES ON THE ACTION OF GROG IN CERAMIC BODIES.

BY

S. Geijsbeek, St. Louis, Mo.

In taking up this subject, I wish to call your attention to the fact, that although we find in all the literature some data as to the action of the regular ingredients of ceramic bodies, such as clay, quartz, feldspar, sand, whiting and other materials, we find but little information in regard to the action and properties of burnt clay-material, commonly called "grog."

Dr. Wilhelm Schumacher, in his book "Die Keramischen Thonfabrikate," devotes a chapter to the use of grog, in connection with making saggers and fire clay slabs for pottery use. He does not cite any experiments, and his remarks are only general. He states that the coarse grog, which is used, runs in size from 4 to 7 mesh per inch, and he considers fine grog that portion which remains on a 36 mesh screen.

H. W. Edwards and A. Leese[1], in a paper before the North Staffordshire Ceramic Society, give the results of their recent investigations about the grog used with sagger marls.

Having an opportunity to study grog at closer range than it has been my privilege in my investigations so far, I will give a few notes on this subject. While they are of a general character, I hope to point out that there are a good many facts about grog and its actions, which should be taken into account when we use grog in ceramic bodies.

Definition.

Langenbeck[2], in his Chemistry of Pottery, calls grog: "Refractory clay, which has been burned and ground, and so sifted that only particles of the size of split peas to

[1] Transactions North Staffordshire Ceramic Society, Vol. II.

[2] Chemistry of Pottery, p. 161.

beans are used, the finer material and dust being discarded. This material is known to potters as grog."

Dr. Post[3] states: "Grog is like sand, to be used on non-plastic material to counteract the shrinkage of clays."

Prof. Wheeler[4] says: "The dilutents or 'shrinkage-reducers' that are used are sand or crushed quartz, burnt clay, crushed brick and pottery or 'pitchers,' which, under the technical name of 'grog,' are used as freely as the clay permits."

From these three quotations there seems to be a divided opinion as to what grog really stands for. Wheeler includes everything which is non-plastic in the burnt and unburnt state under the name, and classifies shrinkage-reducers as being grog also. Fine ground sand or quartz, commercially known as flint, is certainly never called upon to fulfill the function of grog.

Langenbeck's quotation is nearly correct, only I differ with him in regard to the discarding of the fine material and dust, and in that it is not necessary for grog to be refractory.

The definition which I favor is: "Grog is burnt clay or its burnt products in single or compound bodies, in the ground state, coarse or fine, according to the use to which the material is put."

Classification.

Grog is used for various purposes, and the products created by its use can be divided into two general classes.

First:—High temperature or refractory products, and

Second:—Low temperature or non-refractory products.

It will be, therefore, proper to divide grog also into two classes, refractory and non-refractory grog.

Refractory Grog: Grog of this class will stand high heat, and has fire resisting qualities. Grog thus classified

[3] Chemische-technische Analyse, Part, Kalk, Cement and Thonwaaren.

[4] Missouri Geological Survey, Vol. XI.

is used for all refractory clay materials, fire bricks, gas retorts, glass pots, tank blocks, furnace linings, saggers, and other fire-clay products.

Non-refractory Grog: Grog of this group is principally used as a shrinkage reducer, and the fire resisting qualities are not called into play in the finished product. Such grog we find in bodies used for terra cotta, building material, bath and laundry tubs, sinks, wall, floor and glazed tiles, in fact, we find it in all bodies in which grog would be a desirable ingredient, but where the material does not need any fire-resisting qualities.

Refractory Grog.

The grog used in this group can be made from different materials and can be used in different ways. Only refractory materials, such as fire brick bats, broken refractory materials are used for this purpose. Where the supply of these materials is limited, or their use is not desired, refractory clay is calcined direct, and this product is used for grog.

It is only natural that grog, being a burnt material, cannot be used in the same manner for all purposes. Some products demand coarse grog, others a finer material, some need large and others small quantities of grog in order to give the desired results. It becomes a problem for every manufacturer of refractory material to determine what size of grain and quantity of grog is best suitable for the various products which he is manufacturing.

Prof. Wheeler[5] has given us last year some very valuable information on the conductivity of heat through various fire clay bodies. The results which he obtained show distinctly that the fireclay itself, the quantity and the size of the grain of the grog, plays a very important part in the usefulness of the fireclay products.

Some English investigators[6] found that the resistance to fracture by sudden temperature changes, will increase with the increased size of the grain of the grog, and they

[5] Transactions American Ceramic Society, Vol. VI.

[6] Transactions North Staffordshire Ceramic Society, Vol. II.

also found that increasing the quantity of a given size of grain has no effect on the resistance to fracture by sudden temperature changes.

From these few points it will be seen that the size of the grain of the grog plays a more important part than the quantity of grog used, as far as sudden temperature changes are concerned.

The old method of using the same quantity and the same size of grain for all products, whether it is grog for a gas retort, or grog for a firebrick used in smelting furnaces, has proven to be a most expensive method, and progressive manufacturers are using grog to suit the conditions for which the product is made.

It is evident that the mixture of refractory clay material, with grog, used for a gas retort, should be different from that used for a glass tank block. In the first case, the mixtures should be so compounded that the retort will stand rapid cooling and sudden charging, while in the other case it should stand the test of the continuous action of molten glass.

Non-refractory Grog.

The grog used in the second group is used more in the nature of a non-plastic material, and the fire-resisting qualities have no bearing on the products. Almost any clay product in the burnt state will answer for grog used for these purposes. Where the color of the body is to be light, only burnt material of a light shade should be used, but where the color is not essential, as in buff, brown or red clay bodies, any burnt clay material can be used. Brick bats, broken sewer pipe, broken terra cotta, broken pottery, etc., anything which otherwise would be called waste, is suitable for non-refractory grog.

The amount of grog which should be used depends on the properties of teh clay and the ware, which is to be manufactured.

The size of the grain of grog depends largely upon the size of the piece to be made, and the final finish which the product should show after burning. For large pieces large

size grains, and for small pieces, a smaller size of grains would be most suitable.

It is evident that the grog of this group has more of a physical function, and the grog of the first group exercises more of a chemical effect.

The grog used, for instance, in a terra cotta product, should be finished smoothly, with a close grained surface, showing no surface cracks, and grog and clay should form a dense body which should have weather resisting qualities. The gas retort has a coarse looking appearance, the surface, while smooth, is uneven, full of small cracks, the body is open, so much sometimes that a glaze has to be applied on the inside in order to make it impermeable. The grog thus used has produced a body which may be subjected to sudden temperature changes.

Since refractory and non-refractory grog have several features in common, it would be best to discuss these features under one heading, as, what applies to grog used in making refractory products, will also apply to the grog used in non-refractory products, as long as the ware is still in the unburnt state.

General Properties and the Size of Grain of Grog.

The addition of grog to ceramic bodies, may they be porcelain, whiteware, stoneware, terra cotta or refractory bodies, has the same purpose, as far as the properties in the clay state are concerned.

The chief features are:

1. To counteract shrinkage in the green state.
2. To decrease plasticity.
3. To increase the drying qualities.
4. To insure safe burning.
5. To counteract shrinkage in the burnt state.

If a clay or body shrinks more than is required, an addition of grog will decrease this shrinkage.

If a clay body is too plastic, which will make it hard to handle, and blending with a clay of less plasticity is not advisable, an addition of grog will make such clay or body easier to handle, and will decrease the plasticity.

If a clay or body is of the right shrinkage and plasticity, but is not safe in drying qualities, an addition of grog with an increase of some of the clay contents in order to overcome the additional shrinkage, will materially improve the drying qualities.

If a clay or body works properly in the green state, but checks in the burning, an addition of grog will usually overcome this trouble.

In order to obtain some data in regard to what size of grain of grog is used in practical work, five samples of grog were secured, which were taken at random from the regular run of factory work.

These samples were first screened through a half-inch mesh screen, and the product which remained on a four mesh screen is called half-inch mesh grog.

That part which passed through the 4 mesh was collected on an 8 mesh screen. All that remained on this 8 mesh is called 4 M.

8 M grog represents the product which passed the 8 mesh, but was left on a 12 mesh screen.

12 M grog passed through a 12 mesh, but was left on a 24 mesh screen.

24 M grog passed through a 24 mesh screen, and was left on a 32 mesh screen.

32 M grog represents the product which passed through a 32 mesh, but which was left on a 60 mesh screen.

60 M is that fine material which passed all through a 60 mesh sieve, and was not screened any finer.

The samples of grog examined in this manner were:

No. 1. Grog used for high grade terra cotta, mostly used for glazed ware.

No. 2. Grog used for bath tubs, laundry-sinks, etc.

No. 3. Grog used for ordinary building terra cotta.

No. 4. Grog used for high grade fire-brick.

No. 5. Grog used for saggers, used in whiteware pottery.

Percentage Composition of Grog, Relative to Size of Grain.

Size of Grain.	1	2	3	4	5
½-in. Mesh	0	0	0	0	4
4-Mesh	0	0	0	0	47
8-Mesh	0	4	2	3	19
12-Mesh	1	23	13	17	13
16-Mesh	21	19	15	18	10
24-Mesh	11	10	11	11	2
32-Mesh	23	13	18	18	4
60-Mesh	44	31	41	33	1

Taking these results together and dividing the grog into three grades, coarse, fine, and dust, and by which we include:

Coarse grog, everything which does not pass a 16 mesh screen.

Fine grog, that which passed through a 16 mesh but remains on a 60 mesh screen.

Dust grog, is all fine material, which passed the 60 mesh.

We obtain thus the following percentage compositions, regarding to size:

Size.	1	2	3	4	5
Coarse	1	27	15	20	83
Fine	55	42	44	47	16
Dust	44	31	41	33	1

Classifying these results for practical work, we can take grog No. 1 as being a fine product, grogs No. 2, No. 3 and No. 4 as being the regular product used in most factories, and grog No. 5 as being a coarse product, and we obtain the following averages:

Size.	Fine.	Regular.	Coarse.
Coarse	....	21%	83%
Fine	56%	44%	17%
Dust	44%	35%	....

As it was interesting to know whether the different sizes of grain of grog of the same quantity exercised different results, and also to find whether the idea, so far accepted, that the larger the size of grain the greater the porosity, the quantities remaining the same, is correct, the following experiments were made.

The clay used for bond clay with the grog, in these experiments, was a fairly plastic, light yellow burning potter's clay, used for terra cotta purposes, from Glencoe, St. Louis Co., Missouri.

The rational analysis of this clay is:

Clay substance	92.37%
Feldspar	2.16%
Flint	5.47%

The shrinkage of this clay is 14.4%, and its porosity is 2.3%, at cone 7 heat. All the samples were burnt in the same kiln at a heat of cone 7.

The grog used for these experiments was made of broken terra cotta. The shrinkage was entirely eliminated from this grog, as it was burnt at a higher heat than the burning temperature of the trials. The different sizes were obtained in the same manner as the five samples screened before.

The trial pieces were made from plastic mixtures, which were allowed to soak twelve hours before using. They were well wedged, and as near of the same consistency as it was possible to make them.

Composition of Grog Mixtures.

Trial.	Size of Grain of Grog.	1	2	3	4
A	12 M.	Clay	Clay	Clay	Clay
B	16 M.	90%	80%	70%	60%
C	24 M.				
D	32 M.	Grog	Grog	Grog	Grog
E	60 M.	10%	20%	30%	40%

The burnt samples form a very interesting series. It contains specimens such as we find in the refractory line, and among terra cotta bodies.

The series A, B, C show the small surface cracks of fireclay products, while series D and E show the terra cotta finish as we usually find it on this product.

The shrinkage of these trials was taken from the green state to the burnt trial, and the total shrinkage was also measured. It was first intended to take the shrinkage from green to dry, and then the fire shrinkage, but inasmuch as the shrinkage of all products are figured from the mold to the finished product, it was found best to adhere to factory practice as much as possible.

The shrinkage of these trials are tabulated herewith:

Total Shrinkage in Percentage.

Trial Number.	1	2	3	4
A	8.8	5.6	4.6	3.7
B	8.7	5.8	4.4	3.6
C	9.1	6.2	4.6	3.8
D	8.6	6.0	4.5	3.7
E	9.2	6.0	4.5	3.7
Average	8.9	6.0	4.5	3.7

There is only a slight difference between the shrinkage of these trials in the same class.

While a 10% addition of grog to a clay can reduce the shrinkage from 14.4% to 8.9%, or 38.2%, twice this amount of grog can only produce an additional decrease in shrinkage of from 8.9% to 6.0%, or a reduction of 20.1%. A 30% grog addition brings this shrinkage down to 4.5%, or reduces the same an additional 10.4%, while a 40% addition brings the total shrinkage down from 14.4% to 3.7%, which makes only 5.5% reduction as compared with a 30% addition of grog.

The absorption tests which were made, give an idea in regard to the increased porosity of the trials with additional grog. The trials were dried to expell all moisture, and were weighed directly after being taken from the drying bath. They were soaked in distilled water for 24

hours, and weighed again. The amount of water which was absorbed indicates the porosity of the trial.

The following results were obtained:

Absorption, in Percent of the Dry Weight.

Trial Number.	1	2	3	4
A	7.6	9.0	10.2	10.6
B	7.7	9.2	10.8	10.5
C	7.3	9.0	10.2	11.2
D	7.6	9.7	10.3	10.7
E	7.0	9.7	10.1	10.5
Average	7.4	9.3	10.4	10.7

Like in the shrinkage trials, we find here also that the absorption does not differ greatly in the trials of the same class.

A 10% addition of grog to a clay mixture will increase the porosity from 2.3 to 7.4 percent., or nearly 221 percent., while 20 percent. of grog will increase this porosity 304 percent., 30 percent. grog shows an increase of 352 percent., while 40 percent. grog will increase the porosity from 2.3 percent. to 10.7 percent., or nearly 365 percent. In tabulated form, we obtain the following table:

Clay Mixtures with	Decrease in Shrinkage.	Increase in Porosity.
10% Grog	38.2%	221%
20% Grog	58.3%	304%
30% Grog	68.7%	352%
40% Grog	74.2%	365%

Summary of the General Properties of Grog.

We can deduce the following conclusions from the results of these experiments:

1. The size of grain of the grog has no effect on the shrinkage or porosity, providing the percentage of grog remains the same.

2. An increased percentage of grog does not give rise to a proportional decrease in shrinkage, nor a proportional increase in porosity.

3. The first 10% addition of grog to a clay body reduces the shrinkage and increases the porosity far in excess of any subsequent increase of the percentage of grog.

4. The shrinkage and porosity will be affected to a less extent by an increase of the percentage of grog, the higher this percentage is.

There are several other points which should have been considered in regard to these experiments, but which were omitted on account of lack of time. Especially I want to mention a test in regard to the tensile strength of the green and burnt trials. It should also have been determined whether these same results, in regard to shrinkage and porosity could be obtained with other clays, like fireclay, or red burning clays.

While this paper only deals in a general way with grog, the special features of grog as to fire-resisting qualities should not be lost sight of. I trust that these few remarks will be taken to heart by some of our members in the fire-clay line, and result in a paper which will determine what effect the size of grain and the percentage of grog has on the fluxing properties of fire-clay products.

In conclusion the writer desires to extend his thanks to the Winkle Terra Cotta Co., of St. Louis, who kindly furnished all materials for these experiments and burnt the same; to Mr. Ernest Mayer, of Beaver Falls, to Messrs. Bowman, of Trenton, N. J., and to Mrr. H. J. Volz, of St. Louis, for their kindness in furnishing the writer the different samples of grog from their factories.

DISCUSSION.

President Gates: We have put in a machine and have begun a series of tests along the same line. It has been a very interesting question to me, and the question to which Mr. Binns calls attention will be considered later —the effect of grog in a body on sudden heating and cooling. I have been endeavoring to start some research in

that direction. If we put fire brick in a furnace which is to stand continued and intense heating, we use one fire brick; if it is to stand sudden heating and cooling, we use another kind. Neither one will perform the function of the other under the same condition of affairs. Another interesting thing to me is the question of the shape of the grog. A good many years ago I conceived the idea of using quartz sand, in order to avoid grinding. I found it would not do at all, and I concluded the hindrance was to be found in the shape of the round particles, while the particles of the grog we were using were rough. It always seemed to me that they formed the skeleton of the body, corresponding to the bones of the human body, holding up the body; and the contraction of the body wedges them together.

Mr. Binns: I am rather inclined to challenge this statement. You have left out of consideration the difference in chemical composition between the quartz and grog. My idea is that it has nothing to do with the shape. The quartz grains have a different coefficient of expansion from that of the grains of grog.

President Gates: The point I had in view referred to the drying, before the ware went into the kiln. On examining this particular sand, I found the particles were round, globular. It was from soft sandstone rock, and I had previously considered the particles to be angular until I examined them. The chemical composition would not come into consideration until the clay is heated.

Mr. Parmelee: I tried experiments with sand—fire sand, consisting of very sharp and large grains. The only result was a punky body, with no strength. It seems the trouble is the coefficient of expansion of silica. All grog having been previously burned, does not have the tearing or rending effect when heated again.

Mr. Hull: I want to say in connection with the point raised by Mr. Binns regarding the difference in physical properties, that the matter of difference in shape of grains comes in where we are using the same materials, chemi-

cally, as in making silica brick. The idea is to bind the particles together with as little lime as possible, and rather than use silica sand already ground, the manufacturers take the hardest quartz rock they can find and grind it, in preference to using the already ground sand.

Mr. Burt: What struck me as so astonishing in Mr. Geijsbeek's paper was the statement, so contrary to what we have all been accustomed to believe, that the use of coarse or fine grog made very little difference in the shrinkage. It is decidedly contrary to anything we have been accustomed to believe. Mr. Walker and myself have been carrying out some calculations on his trials. We estimate his shrinkage with coarse grog is 3.9%, while with the fine grog it is 6.25%. As close as we can get to it with a rule, there is a shrinkage of 5-64 inch with coarse grog, and 8-64 inch with fine, which gives, when worked out in percents, 6.25% for fine, and 3.9% for coarse. I would like to ask whether Mr. Geijsbeek has further checked up his figures?

Mr. Geijsbeek: The measurement of shrinkage is a very difficult matter. While very fine calculations may bring it to what you brought out, these trials have been measured in the way in which we determine the shrinkage in the factory.

Mr. Hottinger: I think it is rather out of place to calculate shrinkage from so small a sample. In commercial work we would not figure from such small sizes. We want a piece at least two feet long. My experience with fine grog is that we get a little more shrinkage than from coarse.

Mr. Geijsbeek: As Mr. Hottinger says, some difference will be observed. The point is, it has been the accepted assumption that we get a large shrinkage.

Mr. Bowman: My experience in the practical use of grog confirms Mr. Geijsbeek's statement that the size of grog does not matter, or interfere with the shrinkage in the actual making of commercial pieces.

Mr. Wheeler: What is the character of the ware?

Mr. Bowman: Fireclay.

Mr. Burt: Was the difference in the grog as large as that shown by Mr. Geijsbeek, ranging from mesh four to fine dust?

Mr. Bowman: It was between the middle and fine.

Mr. Burt: I would like to ask if Mr. Geijsbeek, by chance, preserved samples of these bodies? In which case it would be feasible to box them up and send to our tensile strength man here, Mr. Stover, and get him to test them for us.

Mr. Geijsbeek: I did not have time to test for tensile strength. In making my samples I made provisions for that and if any gentleman wants to see them, I have a set of trials in the green state.

Mr. Stover: My apparatus would not handle samples of that kind.

Mr. Geijsbeek: I was considering using Fairbanks' testing machine, but to do that I would have had to make new samples, in order to get briquettes of the right size to use on the testing machine. If it will result in any benefit, I will undertake to make two foot or one foot pieces of different sizes of grain.

Mr. Burt: It would be very valuable to take the extremes.

Mr. Geijsbeek: The main point is, that there is not enough difference in shrinkage of each series to make a decided showing. Within reasonable limits, the difference in size of grog does not interfere with shrinkage.

Mr. Wheeler: How many samples of each did you average—did you take one of each size only, or a number of trial pieces.

Mr. Geijsbeek: On three sets, so that the results are the averages of three pieces.

Mr. Wheeler: Were the three fairly uniform?

Mr. Geijsbeek: Fairly uniform, showing about a difference of eight-tenths of a percent.

Mr. Hull: There is one point which has never been touched on here, in connection with grog, and that is its value in increased density and physical strength, ability to resist absorption in refractory products. That is, in a fireclay mixture we have three, instead of two, things to consider. In the first case we have a plastic, in the second a flint clay. As far as refractory products are concerned, it is effective to add grog to the mixture used in making materials to resist the action of slags or molten metal; to make it impervious by reason of its density; and the same thing is resorted to in making it more resistent to absorption.

REPORT OF COMMITTEE ON REVIEW OF CERAMIC LITERATURE.

Charles F. Binns, Chairman.

SPRECHSAAL.

REPORTED BY S. GEIJSBEEK.

In numbers 2—11, 1904, a series of articles has appeared giving the results of extensive experiments, by Dr. Edward Berdel, with bodies composed of kaolin, feldspar and quartz. The final results of this investigation may be summarized as follows:

1. Fused feldspar, when cooled, suffers a decrease of 0.2 percent. in specific gravity, as compared with raw spar. This phenomenon does not take place suddenly, but begins at cone 1 and ends at the melting point of the spar.

2. Quartz loses in specific gravity from the very start of its heating up. This decrease, which is in close connection with its expansion, is very regular, without showing any changing point.

3. Shrinkage and porosity of Zettlitz Kaolin show a decided change at about the same temperature as feldspar.

4. The action of feldspar on the vitrification of bodies is already noticeable at cone 1. The use of feldspar in low temperature bodies is therefore correct.

5. The effect of feldspar in high heat bodies starts with the melting point of feldspar, and its action in the low heat bodies coincides with the change in specific gravity of burnt feldspar.

6. The vitrifying action of feldspar becomes greater the finer the grain is, and to such an extent that very fine feldspar may vitrify Zettlitz kaolin at cone 2.

7. Quartz retards the shrinkage and vitrification of clay substance at low temperatures, but this action is less pronounced at about cone 1-2. But by a continuation of the burning the porosity again increases, and the pieces will increase in volume ultimately.

8. Quartz-clay substance bodies have certain properties when mixed in known percentages, depending on the materials used. It has been shown that bodies consisting of 50 percent. quartz and 50 percent. clay substance have maximum porosity, and than an increase of quartz will decrease the porosity.

9. Quartz loses its effect in part by increased fineness.

10. The plastic Halle kaolin seems to be more affected by burning than the Zettlitz kaolin. The fire action is the greater, the finer the clay is washed.

11. Halle kaolin contains large quantities of fluxes, which are included in the "clay substance" of the rational analysis.

12. An increase of quartz retards vitrification. An increase of feldspar increases it. A small increase in quartz, in clay-bodies, will destroy the vitrifying qualities at low temperatures, while a small increase of feldspar will materially assist vitrification.

MONITEUR DE LA CERAMIQUE DE LA VERRERIE.

REPORTED BY C. W. PARMELEE.

April, 1904.

Messrs. C. F. Bochinger and Soehne have found that natural and artificial corundum do not change in volume when heated, even though this may be done repeatedly. Also they are unaffected by sudden changes of temperature and resist the action of acids and alkalies. For the manufacture of pyrometer tubes, etc., the authors suggest a mixture of 64 parts of corundum, which has passed through a screen of 60 meshes, to the square centimeter, with 37 parts of clay and 9 parts of powdered corundum. For electrolytic diaphragms, equal parts of corundum and washed kaolin are used. These diaphragms are said to be extraordinarily porous, little permeable to liquids, having small electrical resistance, are little affected by alkalies, and are scratched with a knife with difficulty.

September, 1904.

M. F. Garros has made use of amianthus (a species of asbestos) in the production of ceramic ware. He says that its use in the manufacture of sterilizing tubes is well known. Alkaline glazes for these tubes he found too easily fusible, and consequently well absorbed. He was more successful using an enamel with an oxide of tin base. These withstood a temperature of 1200°-1250°, and furnished a surface having theoretically more pores than particles.

He has also obtained the curious result of a body having a great porosity, and at the same time translucency. At a higher temperature, 1650°, the body particles fuse together, giving a very solid porcelain biscuit. At still higher temperatures a glass is formed.

The porous body in thickness of 2 to 3 mm. has an electrical resistance of 0.02 to 0.03 ohms. It is therefore suitable for use in experiments in osmosis, electrolytic work, etc. Mr. Garros has prepared a body and its glaze, both containing amianthus, which he found suitable for use in the manufacture of electrical insulators. The body became impermeable at 1500°-1550°. The glaze matured at 1600°.

October, 1904.

Description of a shaft furnace, heated by electricity, for the production of lime or cement.

November, 1904.

A method for the pulverization and purification of some varieties of fluorspar is found in the simple calcination of the mineral. The organic matter is destroyed, and the rock breaks into a powder. Portions enclosing silica or silicates are not affected except that they develop a yellow color. These fragments may be employed in the manufacture of hydrofluoric acid while the powder obtained is very pure. The mineral, barium sulphate, is said to act in a similar manner.

BULL. DE LA SOC. D'ENCOURAGEMENT POUR L'INDUSTRIE NATIONALE.

REPORTED BY HARRISON EVERETT ASHLEY.

1905, 107, (1), 19.

Researches Upon Ceramic and Allied Subjects.

In his presidential address, M. H. L. Chatelier gave a list of objects for study, for which the Society has recently made grants. Those of ceramic interest were as follows:

Year Began	Sum granted (francs)	Object of the research	Experimenter	Publication in the Society's Bulletin
1891	3000	Calorific power of fuels	Mahler	(1892) [4], 7, 319-374.
1894	2000	Studies upon porcelain	Damour	(1897) [5], 2, 191-215-322-355.
1898	1000	Dilatation of ceramic bodies	Coupeau	(1898) [5], 3, 1275-1309.
1899	1500	Variation of volume of cements	Deval.	(1900) [5], 5, 31-54, 267-270.
1901	3000	Deposits of clay in France	Laville.	To be printed.
....	3000	Analyses of the clays of France	Lavezard.	To be printed.
1903	3000	Properties of the clays of France	Lavezard.	To be printed.
....	1500	Tests upon the bending strength of cements	Deval.	Uncompleted.
1904	600	Porcelain insulators	Granger.	Uncompleted.
	20600			

The total of grants for all scientific studies was 63,500 francs.

1905, 107, (1), 185.

A New Process of Plaster Burning.

A chemical engineer, M. L. Perin, has invented an apparatus to secure a rational and economical heating of the gypsum, and able to obtain with certainty from a gypsum of given water content a plaster likewise of given water content, and of which the rapidity of setting has been determined in advance.

The gypsum is fed by two hoppers into two drums, or revolving furnaces, placed each side of a coke fire, the gases of which traverse these drums, and, after its heating, the plaster falls out into hoppers, from which it is removed after cooling by conveyors. The fuel economy results from supplying the fire with forced draft, preheated by passing through the discharge bin, and by passing the hot waste gases through the charging hoppers, preheating the gypsum. The process is said to be under exact control.

Each revolving furnace takes a three-ton charge of gypsum; it makes one-half revolution per minute. With a coke consumption of 40 kilograms per hour, it takes about three and one-half hours to produce about 2550 kg. plaster per drum, when producing from gypsum with 22.50 per cent. water a plaster with 7.70 per cent. water. The coke consumption is said to be 27.5 kg. per ton of plaster instead of 170 kg. with the older forms of apparatus.

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IRIDESCENT STAINS ON GLASS.

BY

HARRISON EVERETT ASHLEY, East Liverpool, Ohio.

This article will give a short statement of the theoretical basis of iridescent effects, some references to the literature of the subject, and an account of a series of tests in which the presence of metallic silver in the glass was found to intensify very greatly the richness of the colors obtainable, as well as to permit a large variety of coloring agents to be employed.

Iridescence, the property of exhibiting colors like those of the rainbow, is considered to be produced by the reflection of light from both the upper and lower surfaces of a very thin transparent layer of varying thickness. A beam of ordinary light is composed of light waves capable of giving all the prismatic colors, from the long waves of red light to the short waves of indigo light. If the crest of a red light wave (A, fig. 1) reflected from the upper surface of the thin transparent layer travels along with the crest of a red light wave reflected from the lower sur-

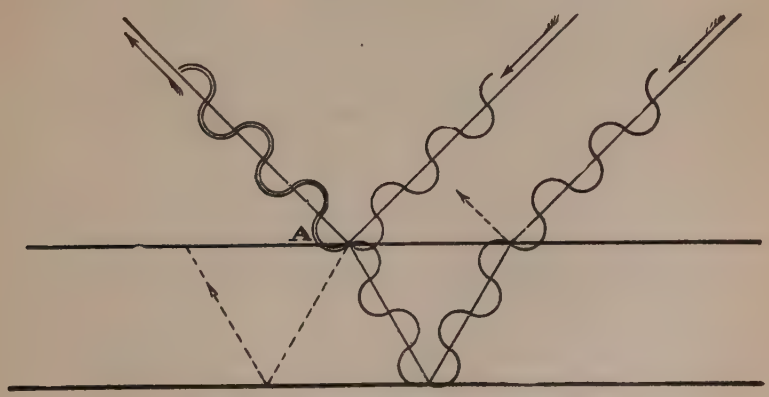

Fig. 1. Reinforcement of Waves.

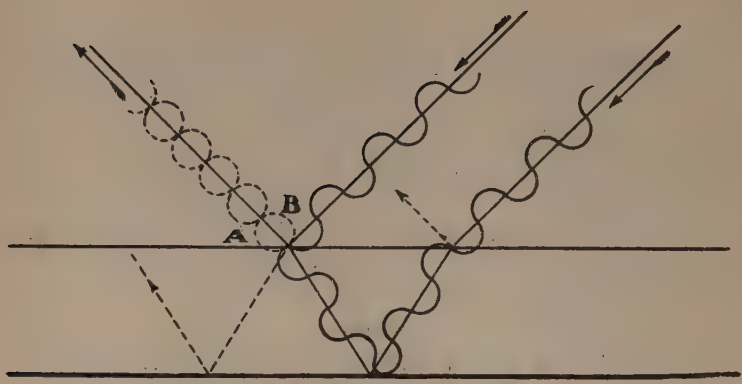

Fig. 2. Neutralization of Waves.

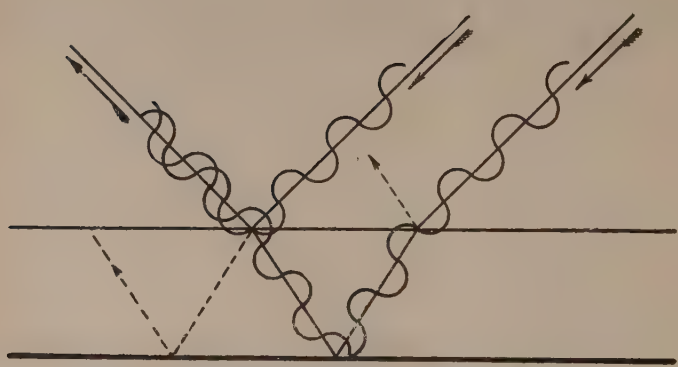

Fig. 3. Partial Neutralization. Average Condition.

face, the human eye will view the sum of the two. But if the hollow of one wave (B, fig. 2) travels with the crest of the other (A, fig. 2), the two will neutralize each other, and red will not be seen. Similarly for the other colors. As a thin transparent layer varies in thickness, successive thicknesses are found most favorable for reflecting back each color, and for cutting off the other colors (especially the complementary color of each). This gives a more or less regularly banded series of prismatic colorings. But a layer of strictly uniform thickness gives a single uniform color.

Suppose now that a substance is divided into several layers (fig. 4), and reflects light at the surface of each layer. The condition rapidly becomes very complicated. Places will be found where the light waves of some color reinforce each other and show distinctly, while in other regions no color will predominate, and consequently the

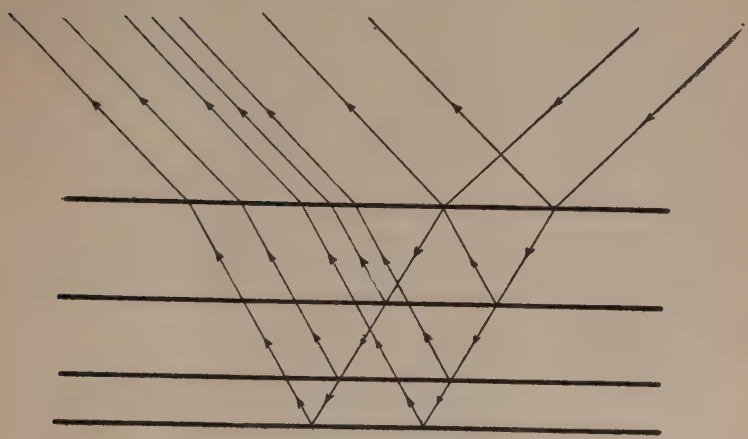

Fig. 4. Iridescence. Pearly Structure.

combination of all, white light, will show. This condition exists in the pearly structure (fig. 5), which is made up of layers of irregular plates.

There are many examples of iridescent films: the soap bubble, which changes in color as it becomes thinner; oil films on water, stone, etc.; oxide films on old glass; oxide, sulphide, and other films on metals[1]; and iridescent films on paper, celluloid, etc.[2, 3].

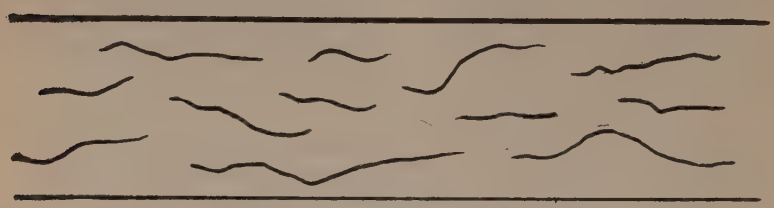

Fig. 5. Pearly Structure.

Iridescent decorations have been applied to glassware much more generally than to pottery, probably because the glass can withstand the fluctuations of temperature in most irising processes better than pottery could.

Paul Weiskopf, the first to make the common process generally known, is thus reviewed in *Wagner's Jahresbericht and Stohman-Kerl's* Dictionary:

"'In the kiln of the porcelain painter (according to Zahn, in the sagger) with thick sheet muffle, at the moment when the highest heat is reached by the glass or porcelain objects to be irised, there is introduced by an opening in the front plate the following mixture:

1. part barium carbonate
0.5 part strontium carbonate
2. parts tin salt

The fumes developed and falling produce the decoration. Strontium gives red, baryta gives blue, tinsalt gives

[1] The numbers refer to the table of references at the end of this article.

various colors. Whichever color is to predominate is increased in amount' . . . . the reviewer can . . . . add that immediately after the additions, the muffle fire must be moderated, where possible completely removed, if one does not want to run in danger of having a matt white precipitate."[4]

"In order to iris in the muffle with sure success, one must have two muffles. In the first the objects are heated gently, about so that the shelf on which they stand is just beginning to glow a faint red. When they have attained the correct degree of heat, they are quickly transferred to the second muffle. At the same time there is strewn upon the floor of the muffle enough iris preparation to fill the contained space with thick vapors. Until this occurs the muffle remains open, then it is quickly closed with the front plate, in which the peephole remains open, and the contents allowed to cool. If carried on in the right manner, all the objects are beautifully and evenly irised. They may, however, fall out somewhat matt, if they are too strongly heated, or if only a trace of the iris preparation happens to be in the muffle used for heating up. A one-sided coating is given if the glass is hotter on one side than the other. The latter may be avoided by repeatedly turning the objects in the heating up muffle. Clouds are formed if a draft of air is prevalent in the muffle during the irising. Metallic flecks are produced, if the iris preparation is brought too near to the object to be irised. Finally, too weak a sheen is produced either if the objects are not hot enough, if the second muffle is not heated hot enough, or if not enough iris preparation is used."[5]

"The irising of such glassware, as is not to be decorated by cutting, is best done in the glassworks at the oven. For this purpose, use is made of such an apparatus as has about the form of the accompanying sketch (Fig. 6). This is a sheet metal funnel, not too high, and further corresponding to the size of the largest object to be irised. It has a cover, that is closed by a hinge. The base of the funnel is closed by thick sheet metal. Near it is a little door. To iris, the base of the funnel is heated with a wood

or coal fire to red heat, the object just made upon the pipe is passed through the opened top into the funnel, the cover closed, and at the same time there is thrown through the little door at the base a sufficient quantity of the iris preparation to fill the whole funnel with dense fumes. The pipe is turned slowly several times upon its axis so that all sides of the object are exposed below, and after a few

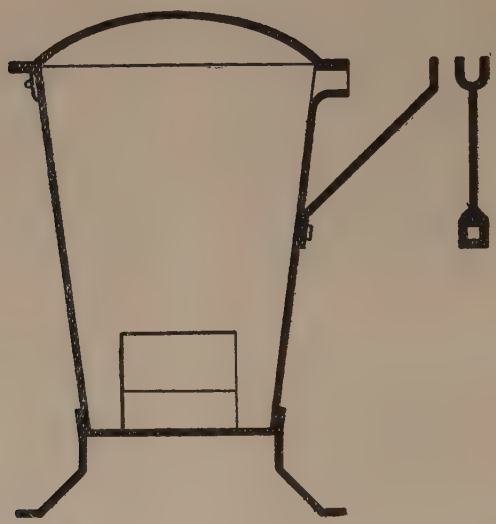

Fig. 6. Funnel Oven.

seconds the irised object may be put into the annealing oven. The operation must be conducted with precision. Such irised objects may be decorated afterward in the usual manner. . . . . The author has previously spoken of the composition of the iris preparation. If one is to prepare it himself, he must take especial pains that the several salts are very finely powdered and intimately mixed with each other, because otherwise the single color tints will not blend into each other, but will be in blotches."[6]

The standard preparation given above is varied by the use of copper nitrate, silver nitrate, bismuth nitrate, lead chloride, lead oxide, silver iodide, barium nitrate, strontium nitrate, etc. Various improvements in the apparatus have been patented, e. g., volatilization of the iris preparation in the arc between two carbon electrodes.[7]

Other processes are noticed by Stohman-Kerl, as follows:

"For the production of a silvery sheen, M. N. Schmitt[8], German pat. 26161, dissolves sheet aluminum in as strongly concentrated hydrochloric acid as possible, applies the solution to the object, and heats it with the exclusion of air to a red heat. Or finely washed pure clay is put upon the glass by means of an adhesive. This is heated to a glow, and vapors of carbon disulphide passed in until the clay changes into aluminum sulphide.

"Fremy and Clemandot[9] produce irising by treating certain kinds of glass under pressure with hot water, to which is added 15 per cent. hydrochloric acid. Or according to Eng. pat 954, of the year 1877, the glass[10] is subjected to the action of a 10 to 20 per cent. hydrocloric acid, at a temperature of 120 to 150° or over, and under a pressure of 2 to 5 atmospheres. By covering certain parts of the glass with rosin, wax, or the like, beautiful decoration may be produced."

The iridescence produced by the foregoing methods is a surface decoration, without great depth or warmth, suggestive of the "lightness and brightness of a bubble." It is frequently characterized by horizontal banding, which I believe due to the greater density of the fumes in the lower part of the fuming pot, or to a vertical variation of the temperature of the object irised.

Very closely related to the irised ware is the lustre ware. The iridescent lustre of lustre ware is also due to light waves reinforcing and neutralizing each other. But in this case, instead of being reflected from the top and bottom of a thin film, the light is reflected from the outer surfaces of exceedingly small, closely and uniformly

placed, equal sized particles, which may be opaque. According to the angle at which the eye views these myriad illuminated points, or lines, coincident waves of one or another colored light is seen.

The theory is about as follows: If we have in Fig. 7, two similar beams of light coming from two narrow slits, A and B, their wave fronts tend to spread out into each other. At the point C, they will have traveled equal distances from the slits A and B, and the waves of every length will reinforce each other, giving a spot of white light. But at some point D, to the right or left of C, the path traveled by the light from the two slits will differ in length by half a wave length of some color, say yellow, that is, the trough of the yellow wave from one slit neutralizes the crest of the yellow wave from the other slit. The light seen at D is therefore not yellow, but its complementary color. At another point E, still further from C, the length of the light paths from the two slits will differ by a whole wave length of yellow light, that is, the crest of a wave from slit A will coincide with the crest of a wave from slit B, and yellow light will be seen better than any other. Thus in passing to the right or left of C, one color after another of the rainbow is seen.

In figure 8, let the series of angles represent the equal sized, equally spaced particles on the surface of a piece of lustre ware. Consider any two similar faces A and B on two adjacent particles. These will reflect two nearly parallel beams of light to any point, and so are equivalent to the two slits in figure 7. But all the particles are similar, so the condition is repeated all over the surface. In consequence, at any particular angle to the surface of the ware, some color is seen at its best.

The *iridescence* of a given spot is a nearly constant color, whatever the angle at which it is viewed, though strongest at the complementary angle to the incident light. The *lustre* of a given spot is a succession of prismatic colors, that varies with the angle at which the spot is viewed.

The lustre decoration is oftener applied to pottery, is

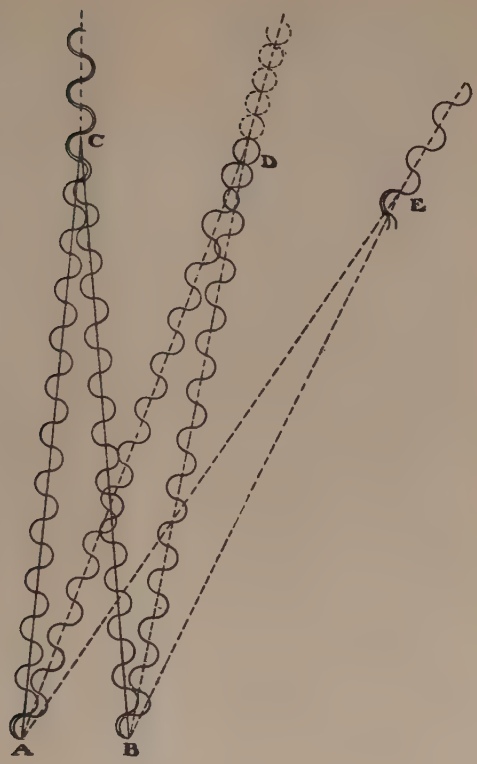

Fig. 7. Lustre.

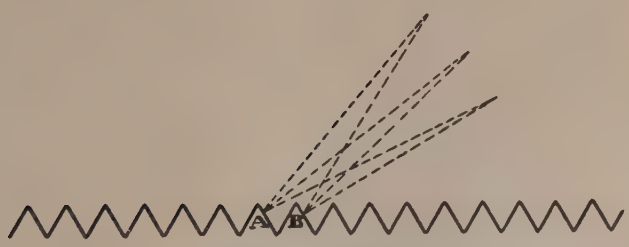

Fig. 8. Lustre.

more substantial in appearance, being of the nature of a colored (sometimes colorless) glaze, with a surface color play (that may be quite faint). It is described by Dr. J. A. Koerner:[11]

"A craft recently revived is the production of iridescent metallic sheen, lustre, upon glazed objects. To explain these little known processes, there will be given here a full account.

"The development of lusters depends upon an artificially produced process of reduction. By carbon in the form of smoke, gas, rosin, or oil, and its incomplete combustion, there is produced a reducing atmosphere. This withdraws oxygen from the outmost particles of metallic oxides, with formation of compounds of low oxygen content, which, on their part, according to the degree of the reduction, show different colorings. When finally with various particles the reduction to the metallic state is complete and the state of division is infinitely fine, the surface shows the characteristic metallic sheen with its light breaking effect.

"The methods of working lustres are manifold. In the first place rosin salts are prepared. A mixture of rosin and alkali is saponified by boiling, and used to precipitate a metallic salt from solution. The voluminous precipitate so produced is washed, dried, and dissolved in turpentine or oil of lavender. The colors so prepared are put upon the object to be lustred, and fired on at a low exactly regulated temperature. Similar lustre colors are obtained by the careful introduction of metallic salts into melted rosin, and dilution with oil of turpentine. Another practicable process is to take pieces already fired and glazed, whose glazes contain smaller or larger amounts of definite reducible oxides, fire them in a specially constructed oven to dark red heat, and then expose to a reducing atmosphere. . . . . "The lustre techinque is very difficult; the products are more or less chance products, so that a duplication of the decoration in color and tint is impossible."

Stohman-Kerl[12] gives receipts for several lustres from Zsigmondi, and concludes: "The lustres do not occur

with equal beauty on all kinds of glass. Also very much depends on the duration of the heating and cooling, further upon the manner of reducing. The most favorable conditions for the production of a beautiful lustre must be obtained for the different kinds of glass by research. General directions therefor cannot be given."

Other mentions are by Pastorrek[13], Richard Borrmann[14], Thorpe's Dictionary[15], D. Böttel[16], Felix Herman[17], [18], Alex Brongniart[23], Emile Bourry[27], Sprechsaal[25].

Copper and silver are usually present in those glazes that are to be exposed to a reducing flame. Gold and tin are also mentioned.

Having spoken of irising and lustres, I will now speak of the application of silver to glass, since a combination of the two former processes with the latter will be shown by the experimental work of this paper.

Silver chloride[26] added to a glass at the time of its manufacture produces a yellow color by admixture, which, however, has nothing in common with the yellow due to metallic silver from stains, and further has the disadvantage of producing frequently a turbid cloudy coloration.[17]

The present writer suspects the iridescent Tiffany "Favrile" glass of an admixture or stain of some form of silver, judging from the characteristic yellow, brown, or green shades by transmitted light, as well as the brilliancy of the effects.

Silver is mostly employed as a yellow *stain,* applied in various forms to the surface, and penetrating to some depth on firing. A cold process has, however, been described.[18] A stain differs from an ordinary pigment in that it does not stay on the surface but penetrates the material colored. There are very few true stains. Most so-called "stained glass" is not stained at all.

A piece of silver leaf was attached to a piece of crystal glass with oil, and fired in a kiln with ordinary decorated glassware (*Experiment, No. 420*). The silver leaf disappeared entirely, and the glass received a yellow stain.

"The surface of vessels may be rendered lustrous by rolling the hot glass on metallic leaf."[22] There is a German glass on the market that has apparently been so treated, then blown somewhat larger, and finally fumed. The silver leaf has become transparent and cracked, but still has a mirror-like appearance; the glass has become stained yellow by the partial absorption of the silver leaf; and the fumes have developed a magnificent iridescence, ranging from pink to blue.

The finely divided precipitated silver[19] is sometimes used as a pigment. It should be applied rather thickly (to prevent complete absorption by the glass), and after firing requires burnishing to bring out the white metallic appearance. Unfortunately, it tarnishes, and so is little used, although a process for rendering it non-tarnishing has been described.[23]

The best guide as to silver stains is Fromberg,[20] who says: "This color is obtained without the intervention of a flux. The process consists in covering those parts of the glass that are to be stained, with a paste composed of chloride of silver and calcined yellow ochre, both levigated together with water. After the glass has been heated to a red heat in the muffle, the layer of ochre which adheres to the surface is removed by means of a spatula, and the glass is found to be stained. The yellow obtained in this way varies from siskin yellow to purplish yellow. It is not always, however, at the option of the artist to obtain any of these tints whatsoever, for some kinds of glass are stained by the process only bright light yellow, while others are capable of receiving a deep orange colour. The orange colour is frequently only obtained by repeating the process once or twice.

"The relative quantities of chloride of silver and burnt ochre are as follows:

Chloride of silver.....1 part,
Ochre ..... from 6 to 12 parts.

"A greater proportion of chloride of silver would cause the paste to adhere too strongly to the glass.....

The paste is applied in a thick layer to the surface of the glass by means of a paint brush.

"The orange colour is only a shade of the yellow from silver . . . . . and is prepared in the same way, except that for chloride sulphuret of silver in the same proportions is substituted.

"A red colour is also infallibly obtained by using sulphuret of silver. In this case the preparation which was employed for the orange yellow is slightly modified by adding a few drops of sulphuric acid at the moment when it is being used. If no red be obtained at the first laying on of the pigment (stain), it must be laid on a second time.

"The latter colour may be obtained in less time, and with greater certainty, by using glass with which a certain quantity of chloride of silver has been mixed at the moment of its manufacture. For this purpose the glass must be well refined, and contain no excess of uncombined alkali by which the chloride of silver would be reduced too soon. The colouring is then effected in the manner we have already described.

"As soon as the yellow is produced, care must be taken not to let the glass pass into the state of fusion, for in the disturbance produced by the motion of the liquid mass the particles of silver assemble in larger groups, from whence arises a new colour in place of the former. The silver in this state of less minute division assumes a very intense blue colour.

"That kind of glass which, when plastered over with clay, is most disposed to lose its glaze, and which partly or entirely gives up the potash which it contains, seems to receive the best colour."

Fromberg is of the opinion that by the action of the ochre, the alkali metals of the glass are set free, and reduce the silver compound to the metallic state.

"That it is the reduced metallic silver which produces the colour in the glass has been demonstrated by very decisive experiments.

"If we take glass with which 1-200th of its weight of chloride of silver has been mixed, heat it red hot, and in this state cause a stream of hydrogen gas to pass over its surface, the glass immediately receives an intensely red colour, which result is likewise obtained by covering the glass with pure clay."

Another test is the evolution of hydrogen gas upon treating the powdered stained glass with acid.

If one is disposed to follow up the unsatisfactory path of "allotropic" and "colloidal" silver, he may start with an article by J. C. Blake.[21]

Fromberg's views have stood the test of 50 years. The present form is that the paste must contain a metal oxide capable of changing its state of oxidation readily (iron, manganese, copper, etc.) and any one of quite a number of the compounds of silver. The oxides act as carriers of oxygen to the silver, but are permanently affected themselves only to an infinitesimal degree. The silver as oxide passes into the glass, and is there reduced to the metallic state, whereupon the color is manifest. Sulphides, possibly, may also act as carriers (sulphide of antimony).

In Exp. 57b, a piece of crystal glass treated with a silver compound, cupric oxide, and ochre in the proportions 1:1:6, received as deep a stain as the same kind of glass with the silver compound and ochre as 1:4. Apparently, the greater activity due to the cupric oxide carrier made up for the deficient proportion of the silver compound.

Only a small portion of the silver leaves the mixture in a given firing, so the dry powder rubbed off from the fired ware may be reused indefinitely.

As my experimental work on the effect of carriers is somewhat contradictory and will not be further described, certain conclusions only will be mentioned, and must not be given much weight: Silver and silver salts by themselves will stain glass in an oxidizing atmosphere. Copper oxide and a silver salt are less efficient than the same proportions of ochre and a silver salt. But with both ochre

and copper oxide, a smaller proportion of silver salt is necessary. In a carbonaceous reducing atmosphere, staining is apparently hindered to some extent, but not prevented. In an atmosphere of stannous chloride or of aluminum chloride, staining is entirely prevented.

There is no apparent hope that the two processes of staining and iridescing may be combined: the stain must be produced in one firing, iridescence in a subsequent firing; one operation puts the metal into the glass, the second operation colors the metal; one operation requires an oxidizing atmosphere, the other a reducing atmosphere.

A few generalizations will apply to much of my experimental work. In a reducing atmosphere, at a sufficiently high temperature, a large number of chemical substances will affect stained glass so as to change the color reflected to any of the prismatic colors, or to blacken the stain. In a test, a negative result does not prove anything; as by the alteration of some of the conditions, the chemical in question will probably give some coloration. When, on the other hand, a test comes out black, it generally means "too much"—of chemical, heat, or some other condition—and with further adjustment of conditions, some prismatic color is almost sure to be obtained.

All the experiments to be described were performed upon an imported Austrian hard crystal glass, which was first stained with silver (except where specially noted), and then subjected to further treatment.

The trial pieces were usually partly coated with a paste or powder containing the coloring agents, when the agents were non-volatile, and placed in a closed vessel of glass or pottery together with a reducing agent; or, if the coloring agents were volatile at a red heat, both the coloring and reducing agents were placed in the bottom of the vessel, and the test pieces stood above. Ochre was used to dilute the pastes and powders.

In many cases, the containing vessels broke, altering or completely losing the color results.

The tests were usually fired in a small wood-fired test

kiln (Fig. 9), consisting of a sheet iron box set over the fire. The time of firing was from one to two hours, and cooling the same. The temperature distribution was very irregular, there usually being produced both straight and

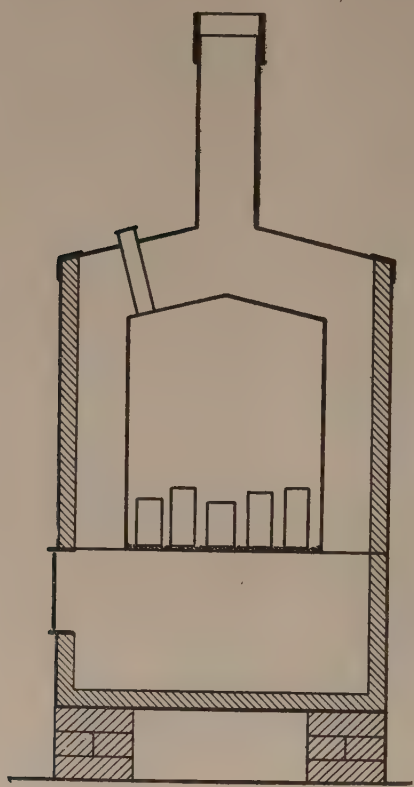

Fig. 9. Test Kiln.

badly warped pieces from each firing. With the larger pieces, however, a better degree of uniformity was attained. Temperatures were judged by the eye, the aim being to give all the heat the glass would stand. When underfired, a kiln of blanks would be obtained. When firing the larger pieces, a strip of a softer American crystal glass was used

in the same manner as a Seger pyramid. Near the beginning of this investigation, I was promised the loan of a Le Chatelier pyrometer, which was from time to time delayed, and finally unfulfilled. In consequence I spent the greater part of my time looking for variety rather than determining the limits of some particular set of conditions. If any of these results are to be carried out industrially, it will require a very exact determination of conditions and specially designed equipment to insure success.

Several thousand test pieces were fired, of which the larger part were outside the range of good color conditions, but, as a check on my working, one set of good results was repeated perhaps fifteen firings along with other work of widely varying success.

With most of the chemicals used, the acid element or radical seemed to have the most effect on the color; the principal exception being the metal copper, which was extremely active in some cases, giving a characteristic red tinge.

In the detailed consideration of the tests, sulphur and the sulphur compounds will be given first place; mainly because they are the only substances commonly used to color the metal silver.[1] The so-called "oxidized" silver ware is really blackened by sulphur. My tests were likewise blackened by an excess. A little sulphur in a tinned cocoa box produced iridescence where the piece of glass rested flat upon another piece of glass; the rest of the piece was dark brown.

Sulphur is its own reducing agent, although the presence of oat straw permits of fully as good results.

A "resist" of ochre moderates the action of the sulphur on the stain, and may be used to produce vari-colored designs; but is liable to stick if the temperature gets too high.

Forty-four test pieces were made to find the effect of silver sulphide in a carbonaceous atmosphere, and these were not altogether conclusive, probably owing to variable conditions as to time and temperature. The best results on the small test pieces were obtained with powders con-

taining silver sulphide, ochre, and lampblack in the proportions 1:27:2 and 1:97:2. But, with a 6 inch globe, 1:4:1 gave a mahogany brown. This globe on refiring in an ordinary glass decorating kiln had its color lightened and thereby improved. This change is remarkable as almost the only case where refiring in a regular kiln affected the color first produced. Better color seemed to be produced with lampblack in the mixture than without. It is a question whether sulphur or silver sulphide combined with the stain.

Various combinations of silver sulphide were tried.

Silver sulphide and ochre with copper oxide added was not improved thereby.

Silver sulphide and ochre with barium nitrate added as 1:2:1 not only gave no color effect, but stuck hard to the surface of the glass.

Ammonium chloride was used instead of straw to produce a reducing atmosphere.

Twenty-seven test pieces were made with copper sulphide. The results were parallel to those with silver sulphide, but rather more satisfactory. Copper sulphide, ochre, and lampblack in the proportions 1:27:2 and 1:97:2 gave the best results. The lampblack in the mixture appeared to be wholly without effect.

Sixteen test pieces were made with copper sulphate. The results were more satisfactory with lampblack than without, but the preparation stuck to the glass if overheated. On a 6 inch globe, there was a horizontal banding of quiet shades, probably a heat effect. The cooler top of the globe was blackened, without color. The coloring very much resembled that of a commercial article that is now made with a silver basketwork. All the tests are characterized by a bluish shade.

Four test pieces with copper sulphate were made, using a reducing atmosphere of ammonium chloride. They were not very satisfactory.

Thirty-four test pieces were made with sodium sulphide, a volatile sulphur compound. Too large a propor-

tion gave dark stains, but with the smaller proportions, some of the most brilliant results were obtained.

Six test pieces were made with sodium sulphide and metallic magnesium mixed as 3:1. No special advantage appeared to result from the magnesium.

Twenty test pieces were made with sodium sulphide in an atmosphere of ammonium chloride, instead of a carbonaceous one. The results were not very satisfactory. Three of the pieces developed a blue sheen, which is probably what Fromberg says is due to aggregation of the silver by heat into larger particles[20], and not at all due to a coloration by the chemicals used.

Thirty tests made with lead sulphide were about parallel to the copper sulphide tests. Twenty-five more tests with lead sulphide were made directly in a large sheet iron box (22 litre capacity) without the use of small glass jars as separate muffles. With lead sulphide and ochre as 1:29 and 1:1000, the tests came out black. Suspecting that the iron box was impregnated with some troublesome chemical, I whitewashed it, and then 1:1000 and 1:10000 gave some very good results, both in uniform bronzes and in mottled shades.

Nine tests made with antimony sulphide and ochre as 1:1 and 1:4, and with lampblack as 1:4:1 were dark and unsatisfactory.

Twenty-six tests made with sulphide of tin were about parallel with the copper sulphide tests.

Nine tests were made with sulphide of tin in a reducing atmosphere of ammonium chloride. They were unsatisfactory.

Three tests were made with sulphide of tin and metallic magnesium, with no apparent advantage from the use of the latter.

Ten test pieces made with sodium thiosulphate were not very satisfactory, but gave some promise.

Thirty-four test pieces were made with sodium thiosulphate and lead acetate. Some bronze colorings resulted.

Twenty-four tests with sodium thiosulphate and basic copper acetate resulted similarly. The best bronze was

from copper acetate, sodium thiosulphate, and ochre as 3:1:396.

Speaking in general of sulphur in its various combinations, there is but little difference which is used, and moreover many of the tests cannot be distinguished from those with other substances, to be described further on. With a few brilliant exceptions, the tendency is to be dark and quiet in tone.

In the first test with copper oxide, a pleasing greenish sheen was obtained. A 10 inch globe was treated with copper oxide undiluted by ochre, in a sheet iron box, with parafine and straw, and fired in a regular glass-decorating kiln. It came out pretty dark, but showing mottlings of dark green and red. A parallel test was made open in the same kiln, with no effect upon the stain. A six inch globe, which had been cleaned with "acid," was treated with copper oxide, lampblack, and ochre, as 3:1:8, in a box in the regular decorating kiln. A pleasing quiet coloration was produced at the top and bottom, but not in the middle. Another globe, thickly stained, and not previously cleaned by acid, developed a somewhat dirty gray metallic color. A ten inch dome came out looking like the bronzed leather shoes children used to wear, with faint pink, blue and violet iridescence. A six inch globe had ochre "resists" put upon it, and was then treated all over with the same mixture. It came out with a mahogany stain, very much the *darkest where the clay resists were.*

A number of tests were made with metallic magnesium, instead of lampblack, with the copper oxide. Two of these developed some bright red and yellow color. This may have been an accident. The others were very dark.

Pastes of silver nitrate, ochre, and lampblack as 2:2:1 and 1:4:2 gave iridescent colorings of no special merit.

About fifteen test pieces with silver nitrate and copper oxide failed to produce anything satisfactory.

Six test pieces were darkened by silver nitrate, potassium bichromate, and ochre, as 1:1:18 and 1:1:198. Not promising.

Three test pieces in a jar (300 cu. centimeters capacity) with forty drops of nitric acid were hardly affected.

Nine test pieces prepared with barium nitrate came out badly stuck up. No promise.

Five tests with bismuth subnitrate also stuck.

Seven tests with manganese nitrate gave little promise.

Eight test pieces with nickel nitrate gave some promise, as did also nineteen tests with cobalt nitrate and twenty-six with copper nitrate. Some of the copper nitrate pieces showed a different coloration outside of the paste than beneath it.

Taken as a whole, the nitrates are much less satisfactory than the sulphur compounds.

Tests of sodium thiosulphate with lead acetate and with basic copper acetate have been already described.

Tests with lead acetate alone, with basic copper acetate, with basic copper acetate and copper nitrate, and with basic copper acetate and cobalt nitrate developed quiet colorations of no special merit.

A test was made with 0.65 grams potassium bichromate, 10 drops hydrochloric acid, and 20 drops sulphuric acid. The volatile chromium oxychloride formed did not affect the stains.

Stannous chloride (tin crystals, chloride of tin), a volatile substance, may act as its own reducing agent, producing brilliant iridescence, but, in the presence of carbonaceous matter, there is a blackening. If the atmosphere is not sufficiently reducing, adherent brown monoxide of tin is deposited on the glass, and, if still more oxidizing, adherent white dioxide of tin is likewise deposited. If the stannous chloride is not able to take care of itself in this respect, ammonium chloride is an efficient volatile reducing agent, and does not interfere with the brilliancy of the product. The use of metallic tin and ammonium chloride produces the same result as the stannous chloride preparation, the ammonium chloride volatilizing the tin as chloride. However, the persistent forma-

tion of adherent oxides of tin almost makes stannous chloride valueless for coloring stains in this manner.

The bad qualities of stannous chloride persist, when used with aluminum chloride, or with metallic aluminum and ammonium chloride.

A remarkable test was made with stannous chloride and copper chloride as 4:1. It was probably underheated. The upper part retained the unaltered yellow stain of silver. Toward the base the color of the stain was altered to a brownish red, *by both transmitted and reflected light.* At the base, the stain was altered to a clear green *by both* lights.

A number of tests of stannous chloride together with barium nitrate, strontium nitrate, lead nitrate and copper nitrate gave negative results.

A test with stannous chloride and silver sulphide gave iridescence of no special promise.

Aluminum chloride resembles stannous chloride with the bad qualities omitted. It, likewise, produces a brilliant iridescence, but requires a separate reducing agent, and is at its best in a carbonaceous atmosphere. Its white oxide, when formed, does not adhere to the glass.

Ammonium chloride is also an effective reducing agent here, and, used with metallic aluminum alone, will produce an effective aluminum chloride.

In a tall jar, on a long piece of glass, a once or twice repeated rainbow banding was produced.

On a piece of stained glass with a white metallic silver decoration, the stained portion was made iridescent, while the white metal was unaffected in color.

A number of tests were fired with aluminum chloride in a sheet iron box. They came out charcoal black. On repeating, the same result was obtained. An almond-like smell was noticed when the box was opened. On this and similar evidence, it was assumed that chloride of iron is a very strong agent to blacken stain. In a later experiment, with ammonium chloride as reducing agent, a six inch globe, fired in a sagger made from two earthenware sauce pans warved upon each other, developed a rich golden

bronze. On repeating the experiment, the pans cracked, but remained in position, and enough chloride of iron penetrated to change the color to a rich olive green.

A piece was spotted with gum arabic and charcoal. Firing with aluminum chloride developed a general pinkish iridescence, which changed sharply to a brilliant green where the markings were.

The vivid golden yellow upon many of the tests is remarkable.

Several pieces were fired with aluminum chloride in two of the earthenware sauce pans mentioned above, with straw and parafine as the reducing agents. Every surface inside the pans was blackened. This very much resembled the blackening obtained with stannous chloride and straw; so, I suppose there was tin or some substance similarly affected, in the glaze of the sauce pans, which was volatilized by the aluminum chloride fumes.

Three tests with aluminum chloride, stannous chloride, and cobalt chloride showed no special promise.

Aluminum chloride, together with copper chloride, gave a peculiar result in experiment 40 v, w, x. Pieces v and w had the usual aluminum chloride effects, while piece x, a much heavier stained piece, seemed to have concentrated upon itself all the special action of the copper chloride. It had a deep rose tint, due to the copper chloride.

In experiment 41 a, b, c, d, the action of the copper chloride appeared to be concentrated in the bottom of the jar. In piece 41a, the succession of colors from top to bottom was:

1. A very rich, clean green.
2. Blue.
3. Yellow green.
4. Violet.
5. Red and copper base.

A piece of unstained crystal glass received a slight ruby tint by both lights (41c). This was also found in a number of other experiments where copper and some chlorine compound were present.

Experiment 32, with aluminum chloride and a small piece of metallic copper, gave some rich colorings, which was later repeated (37 am). Experiment 31 a-i was performed with aluminum chloride in an old copper tea pot. All the glass received a deep coppery red by both transmitted and reflected light, in some cases so deep as to reach opaqueness. This was repeated twice with the addition of metallic aluminum, and the same result obtained. One of the pieces was perfectly metallic in appearance. But where only a small amount of copper was present, some exceedingly beautiful pieces were obtained.

Six test pieces treated with copper chloride, without any reducing agent, were hardly affected at all. But when ammonium chloride was used together with a small piece of copper, a piece was obtained having a fiery red base with slight violet spots, and above this a blue or purple sheet with golden stars.

Tests of aluminum chloride with silver sulphide or with sodium sulphide did not yield anything of merit.

Aluminum chloride with zinc bromide gave some dark tests, while zinc bromide, without aluminum chloride, gave a quiet antique effect.

Aluminum chloride with arsenic iodide gave some dark tests. Without the aluminum chloride, the effects were almost equally unpromising.

Silver iodide gave some quiet tests.

Potassium iodide gave some dark quiet tests.

These latter were not improved by adding to the mixture sulphuric acid or hydrochloric acid.

A commercial bronze powder (Jenkin's 10000) with ammonium chloride as the volatilizing and reducing agent, produced a warm coppery color, but when used in excess, the copper in it made the stain too dark and opaque to be pleasing. The same powder used with aluminum chloride produced a vivid green.

Calcium fluoride produced a slight darkening. With calcium fluoride and ammonium chloride, there was almost no effect. With calcium fluoride and acid sodium carbonate, there was a slight mottling. With calcium

fluoride and sulphuric acid, there was some promising greenish iridescence.

A few words may be said in conclusion concerning ways in which the texture of the glass may be affected. If the ochre used in applying a paste, say 1 millimeter thick, has been previously heated to as high a temperature as the glass is to reach, there will be little effect on the surface of the glass. But if the ochre is raw, its shrinkage on firing will cause the surface of the glass to crackle into a multitude of small faces.

When the glass is overheated and sinks slightly, its surface takes on a beautiful silky gloss, due to a fine horizontal striation, composed of very narrow ridges very close together. But if there are patches of ochre, lampblack, or plaster paris on the surface of the glass, they will reinforce the glass so as to preserve the original smooth surface beneath the patches.

Acknowledgements are due to Mr. W. H. C. Taylor and Mr. J. V. Baron, in whose glass decorating shop, in New Bedford, Mass., these experiments were conducted, for the materials used, and for many practical suggestions, including the advice to try stained glass. The latter piece of advice, and Prof. Orton's suggestion that iridescence is probably on the boundary between the oxidized and reduced conditions of a metal, furnished the starting point for the foregoing investigation.

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ACTION OF REFRACTORIES UNDER LOAD CONDITIONS AT HIGH TEMPERATURES.

BY

LEMON PARKER, St. Louis.

Until recently, the importance of a thorough knowledge of the many factors influencing the life of a refractory material, under load conditions, at high temperatures, has been recognized only by few manufacturers.

As to the engineering side of the question, the demand for modern methods with their extreme temperatures and hard usage, in the struggle to force the largest possible production in a given time, regardless of any rated capacity, results in over-taxing, abusing, and racking to pieces the furnaces, and numerous furnace designs by engineers seeking to excell in this economy, are on the market. Elaborate data is collected, as to the capacity per hour in cubic feet of gas, tons of iron or steel, or bushels of coke manufactured per unit of fuel consumed, but few engineers consider the uniform distribution of heat in its bearing on the life of an oven, except in a secondary way. How many know the temperature of the hottest and coolest part of their furnaces? This is of the utmost importance, as is illustrated by the following instance.

Being called upon to inspect a bench of fire clay tiles in a gas works, said to have failed from undue shrinkage, I found in the flame chamber, directly above the fire-box, at the point where the secondary air of the recuperator meets the gas for combustion, evidence of heat so great that the material was reduced to a cinder, and crushed out of shape by the load of retorts and tile above it. Twenty-eight inches above this point, and in the direct line of the flame, the material was still unchanged but badly deflected by the giving way of the tile underneath it. I was told by the engineer in charge that the heats were not excessive, and he expressed the opinion that the tile were not originally

burnt hard enough, and had shrunken from this cause, throwing the loads on the center retorts, thus causing heavy distortion. Reasoning from his point of view, the temperatures taken on the retort line, barring the lower middle retort, were about right, but he should have measured the temperature of the flame chamber. The so-called shrinkage occurred only in the tiles used as supports to the lower middle line of retorts. The tile, forming piers, and those directly above, were in contact with the excessive heat of the short flame.

I desire to criticise the usual form of flame chamber. It resembles in construction the oxy-hydrogen blow pipe, which we all know furnishes a very short flame and the most intense heat. The gases meet in a mixing chamber and burn just above it as do the air and gas in a recuperator usually made for this class of ovens.

It is a well known fact that the jet known as the calcium light is less intense, but of longer flame because the admixture of the two gases does not occur at a single point. It is also known that the hydrogen is completely consumed; therefore it would be adapted to heating larger surfaces. Why not separate the gas and air jets and set them upright, and nearly parallel to each other instead of at right angles as now, allowing the gas and air to meet just above the line of the lower retorts and in the open settings. The combustion will be just as perfect and not as intense, but more evenly distributed, and by properly regulating the dampers the length of the flame may be controlled.

Returning to my inspection of the bench of fire clay tiles, several samples of tile were sent home, some that were reduced to an absolute cinder, and some that were not affected because of different location, both being of the same clay and mixed at the same time.

Pieces were cut from an unaffected sample and submitted to trial in our test furnace. They showed a heat resistance of 3182°F before fusing, being as refractory as the other samples. The gas men claimed about 2200°F as their working temperature at the retort line, and they also

claim that overheating could not occur, since excessive temperatures would modify the proportion of the by-product to such an extent that it would not be allowed. The question arises: Is this claim correct? Is it not an admitted fact that a temperature of 2650° to 2800°F is often reached in a flame chamber, in order to get 2200° in the open settings? Is this economy, and is it necessary? Something is surely wrong. Why waste this heat at a point where it acts as a destructive agent and does not distribute the heat where wanted?

I do not claim, however, that 3182° existed in the gas furnace examined, but a very high temperature continued for some months, say 2600° to 2700°F. Having the problem of heat distribution before me every day in setting kilns, and having seen the effect of a short flame in our gas fired continuous kilns, which were at first a failure because of the short flame, and its accompanying local intensity, a slight modification on the line mentioned, the separation of the gas and air was made, modifying the arrangement so as to distribute the heat more evenly throughout. Indeed, by proper damper regulation we have forced flames ahead into the water-smoking kiln, at the proper moment, causing it to ignite itself when the gas was turned on.

Having recited the foregoing as the cause of my investigation of the distribution of heat, and its important bearing on the life of a furnace, together with the load-carrying power of tiles within 500° of the failing point, I can only wonder at the neglect of a factor like this in designing or constructing an oven.

We all know that a burnt tile or brick, depending upon its mixture and mechanical construction, will sustain considerable loads when cold, but practically nothing is known as to its ability to sustain loads when soft from excessive heat. This involves the consideration of several designs of gas furnaces, some of them built with the load on the central piers, in the hottest position, carrying 7.5 pounds to the square inch, some 15 pounds, and some 25 or more pounds to the square inch, with heats from 2200°

to 2800°F in the flame chamber. The problem does not seem at first to be difficult, as the material used is supposed to stand a test temperature of from 3000° to 3300°, but a careful study of the subject will show us that refractory substances, differing in fusing point, also have a very wide range of softening, which may be influenced largely by the composition. The best materials as used today in gas oven construction, fired in a test oven from 3000° to 3100°F, result in twenty-four hours in cinder, pure and simple. The same material used at about 2000° to 2200° will last in a gas oven, on an average, thirty months, thus showing a factor of safety over 25% referred to degrees. I am now speaking of the old style benches of 3's, 5's and 6's, with half depth recuperation, or none at all. A study of these designs shows, in the case of 3's, a very small load, in a case of 5's two tiers of two retorts, with one in the center very high up. In the case of 6's the loads are somewhat heavier, usually two tiers of three retorts, but in each and every case the flame space is liberal, and the load carried upon a comparatively cool structure.

These circumstances, together with the light loads imposed, seldom cause trouble, but in the case of 8's sometimes there are two tiers of four retorts each, sometimes two tiers of three retorts each with one tier in the center of two. As to the 9's, there are three tiers of three retorts each. In the case of 8's, with four retorts in a tier, the load is at least 33% heavier than where only three are placed in a tier, but so little consideration is given to the subject that a corresponding increase of area of the tiers carrying the load is seldom added, so that the advantage gained by the increased width of fire chamber is lost, or possibly this four tier form is adopted so that more benches may occupy a given space in a retort house, thus permitting a narrower arch. A direct practical illustration of this load factor in designing was also brought to my attention in the failure of a bench of 8's, with three retorts on the side and two in the center supported on very long piers. The area of these piers was increased

100% in plans afterward made, with the result of no further trouble.

In a bench of 9's the flame chamber width is usually so contracted as to confine the gases, giving a further intensity from this cause, and in addition the central line of retorts has a flame chamber on either side, making the piers and tiles at the level of the mixing chamber still less able to support its load, because all supports are equally and extremely hot. As the factor of space is of the greatest importance in the retort house, the widening of the flame chamber can not be considered, but the point where the mixing of gas and air for combustion occurs should be raised from the floor line by giving both inlets an upper turn, preferably straight up, and separated as much as possible.

Some engineers may raise the point that a sufficiently high temperature could not be maintained if this excess of heat is not carried in the flame chamber, but allow me to ask, would it not be more economical from every point of view to have just the temperature wanted, 2200°, distributed nearly equally among all of the retorts, rather than have 2600° to 2700° where it is not needed, and two feet above it 2200°, and probably further on, at the bottom of the retorts on the outside, only 2000°? I claim that the present flame chamber is not entirely efficient in this respect.

The ordinary down-draft kiln shows a variation of 200°F from the flash wall to the line of the center flue with its ordinary fire-box, long flame, and imperfect admixture of air in a distance of say twenty to twenty-five feet. Why should not a more perfect mixture of gas and air produce a more intense and shorter local flame, and as a consequence greater inequality of distribution?

This is not argument for a return to the old way, but an endeavor to correct an existing evil in the designs of later furnaces.

Perfect combustion should be aimed for, but equal distribution is more important from the economical point of view.

The load factors in designing buildings are carefully calculated, and it seems likewise necessary to study the power of refractory materials to resist crushing strains at high temperatures. A highly refractory fire clay material in the form of brick, at its failing point, will not sustain its own weight. This is well known, but it is not well understood that a wide range of softening exists in all clays, below the failing point.

This softening might be compared to the condition of a piece of molasses candy, very brittle at one temperature, yet it will soften through a wide range before it melts. In fire clay this range of softening can be controlled to a great extent by proper mixtures, as will be shown in a diagram. The engineers should make themselves familiar with these factors by actual tests, and allow a factor of safety both in temperature and load.

It has been demonstrated that a refractory material that will fail in a test at 3000°F, after twenty-four hours, will last 900 days in use at a temperature between 2000° to 2300°. It has also been demonstrated in practice that a load of ten pounds to the square inch has been put upon a furnace without trouble, but there have been cases where a ten pound weight has caused failure, the flame chamber temperature having not been known, but it was assumed to have been excessive, as indicated by tests of samples of the unaffected tile. Why would not a five pound load, including a live load, on piers, be a step in the right direction? It is perfectly feasible. This is a safe load at 3000°, in a twenty-four hours' test, and gives a factor of safety of 50% over a ten pound load, per square inch, and also a factor of safety of 25%, at 2200°, in regard to temperature.

In designing furnaces there is another point to be considered. At high temperatures clays used as bridges bend sometimes under their own weight at comparatively low temperatures, therefore no considerable part of the load should be upon a bridge, but should be put directly upon the piers with a straight downward thrust. The so-called self-supporting setting is wrongly named Their proper use is only to preserve the shape of a retort under

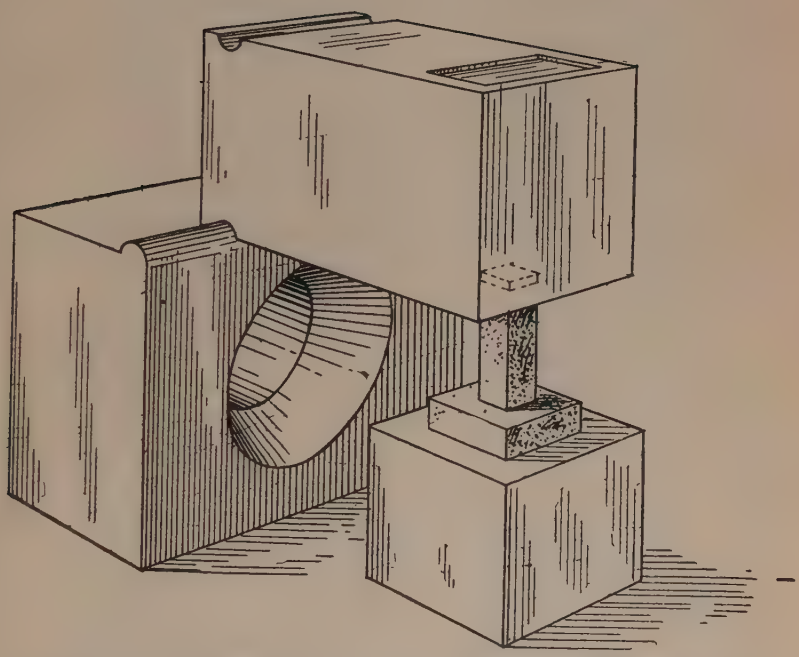


Fig. 1. Diagram showing the arrangement of the test piece and the application of the loads upon it. By the addition of bricks upon the heavy block supported by the test piece the load may be increased.

load, and as they span an opening they should bear no part of the load. They should have as much area as possible in the direction of the horizontal or vertical thrust, consistent with the openings admitting of circulation from the front to the rear of the furnace. Just what effect the strain caused by charging and drawing machines has I am not able to say. Fire clay within its range of softening may be compared to asphalt at 90° F, which will permit a heavy loaded wagon to pass without harm, but should the wagon stand for some time on the same spot it would leave its mark as a deep scar in the pavement. Charging and drawing machines might possibly act in this way in the short time they are in the retort.

In making a test showing the effect of the composition of clay products upon the bearing strength, so many conditions are dealt with that very little information has been obtained so far.

The indications are, that a clay best adapted to carry heavy loads up to the point of incipient vitrification, 2250° to 2300° F, would, beyond that point, not prove entirely desirable, while a more refractory clay, not so good as a heavy load carrier, would carry its moderate load to a higher point.

Three records must be kept; one in regard to the chemical composition, one referring to the mechanical mixture, and one to the composition from the standpoint of the rational analysis. Starting with the chemical side, the effect of fluxes on clay long before failure under load is undoubtedly potent and as yet has not been investigated. From the mechanical stand-point, proper weathering, soaking, slow drying and burning are factors which influence the result very largely but are at present lost sight of, though the factor of the density of a body against bodies composed of loose and coarse grains, is being investigated resulting in evidence in favor of a dense, compact mass for materials under load strains.

As to the diagram (see fig. 1), showing the tests made, graphically, the degrees are shown on the bottom line, increasing in intervals of 50 degrees F. The loads, shown

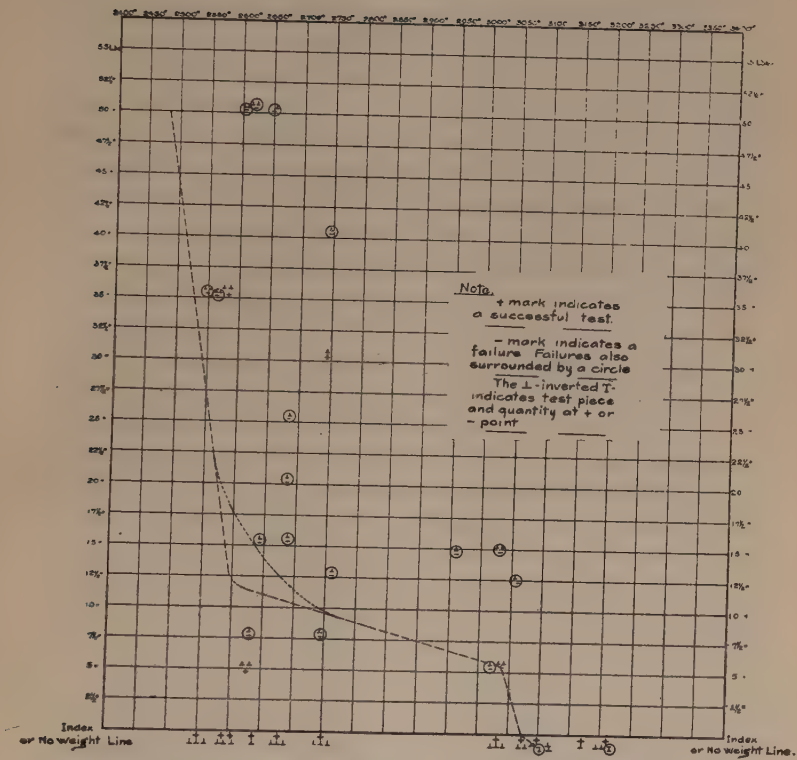


Fig. 2. Results of Load Tests at Difierent Temperatures, ordinates, pounds, abscissae, degrees F.

along the ordinate, increase in intervals of 2.5 pounds. The first line is called the index line. The successful tests are indicated by plus signs. Those with minus marks surrounded by a ring, are failures. The failures at 3100° and above are due to sinking by their own weight and to fusing. There are no failures below 3050° on this line. In starting the test I thought it would be a good plan to use the shrinkage of the test pieces without loads as the limit of shrinkage at that temperature but I found this impracticable as there is such a large variation due to many causes. Hence an arbitrary excess shrinkage was adopted. For some of the samples this shrinkage limit was placed at .125 of an inch and in other cases at .1875 of an inch, in the height of the test piece, measurements having been taken before and after the test. Any shrinkages above this point were considered failures whether due to high temperature, under load or no load.

Beginning on the index line, 3200°, we have recorded one sample as failure and two samples as being satisfactory. Between 3150° and 3200° there is one sample recorded successful. At 3100° we have three samples shown as satisfactory and one sample shown as a failure. Reading backwards from 3200° to this point, there were no loads placed upon the samples. At about 3060° we have two samples upon the index line that did not fail, and one sample with 12.5 lb. load that showed failure. At about 3040° there are shown three index samples that were all right, and with 5 lbs. two samples that did not fail and one that did; at 15 lbs. two samples that showed failure. At about 2960° with 14.5 lbs. load one sample showed failure. At 2750° three show successful tests, and one failure, at 7.5 lbs., two successful tests at 10 lbs., one failure at 12.5 lbs., one good test at 30 lbs., and one failure at 40 lbs. At about 2700° there was one good test at 10 lbs., and three failures at about 2670°, one each at 15, 20, and 25 lbs. At this point, 2670°, there were three index tests and one 10 lb. successful test. Between 2600° and 2650° there were two index, two 5 lb. and one 10 lb. good tests and one 7.5 lb., one 15 lb. and five 50 lb. failures. Between 2550° and

2600° there were five index, one 10 lb., two 35 lb. good tests and four failures at 35 lbs. Between 2500° and 2550° there were two 10 lb. tests and one 50 lb. good test. Between 2450° and 2500° there were two 10 lb. and two 50 lb. successful tests. All of these are standard mixtures that are used daily. Beginning at 3150° we have a line drawn from point 3100° which shows one failure and three successful tests with no load to about 3060° where two successful unloaded tests occur. We can draw the line of successful tests through two 5 lb. loads at about 3040° notwithstanding the fact that a third showed failure. At 2750° we have one failure at 7.5 lbs., one at 12.5 lbs., two good tests at 10 lb., and at 2700° and odd degrees we have one test piece which showed success at 10 lbs. I therefore draw the line of successful tests from 3040° at 5 lbs., where there is evidence of two successful tests against one failure, to about 2710° at 10 lbs., where the success of three samples on the 10 lb. line stands against one failure at 7.5 lbs. at 2750°. Also at 2750° we have one successful test with 30 and at about 2570° two successful ones with 35 lb. loads which are rendered questionable by four failures, and at 2760°, 12.5 lb. and 2750°, 40 lb. and 2670°, with three failures, one each at 15, 20 and 25 lb. Nor is it right to assume that the test shown at 2525° with 50 lb. is correct, because its success is called in question by failures with 35 lb. at 2550°. We therefore draw the line at 50 lb.—2480° almost straight down. There is a break in the line which in some samples may be somewhat sudden, as shown by the smaller curve, or more gradual, as indicated by the longer connecting curve. We might question the correctness of the line of successful tests, beginning at 3040°—5 lb. and 10 lb., 2710°, because there is one failure at 3040°—5 lb., one at 2750°—7.5 lb., and one at about 2630°—7.5 lb. This is where the whole trouble lies due to irregularity of the temperatures or to the slight protection of one sample against another, from the direct blast of the flame. I assume, therefore that some local protection caused the good test of sample at 2750°—30 lbs. Some local intensity of heat caused the failure of one test at 3040°—5 lbs., one test at

2750°—7.5 lbs. and one test at 2630°—7.5 lbs. Accepting the evidence of 2 to 1 at 3040°—5 lb., the line of loads begins here and the evidence of four good tests on the 10 lb. line near 2710° to two failures at 7.5 lb., to one each at 2750° and 2630°, and beginning at the other end at about 2470°, three successful tests at 50 lb., causes the line to be drawn straight down. It is evident from the appearance of this diagram that the tests are not complete as to number, nor are they sufficiently accurate for the several reasons given and other reasons. The test pieces themselves have more of the shape of a post than they should have, being rather tall for their other dimensions. Another fault that has cropped out is that in attempting to make a comparison of mixtures with coarse grains they have not proven successful because these coarse grains affect the carrying power of the material, the cross section being too small in the present samples. It is proposed to alter the shape of the test pieces and to make experiments with larger pieces having the shape and size of brick. In this way a better comparison could be made of the effect of the variation in size of grain and also in composition.

It is for the reasons stated that no attempt is made in this paper to go into the question of composition. That the character of the composition may influence the load factor is shown by results of tests of special mixtures not shown here, although these mixtures may for other reasons not be suitable for the purpose, and it will require much work to adapt them after a complete line of load tests have been made.

I submit this paper in the hope that it will call attention to two important factors in furnace construction that have not received proper consideration at the hands of engineers.

Test Furnace Used in Making Tests of the Load Carrying Power of Tiles Within 500°F of the Point of Fusion.

The furnace consists of a small rectangular box with oil burners. In the side walls at about 9″ above the floor line the tongues of the wall support of the weight pieces are

placed and run the entire length on either side of the furnace permitting tests to be made of either 9″ brick or special test pieces. The weight blocks have two grooves on the same end, on opposite surfaces; on the other end of the weight block there is on one of the two surfaces a square hole ⅛″ deep, a trifle larger than the cross section of the test piece, 1.1-16x1.1-16 inch. On the same end but on the opposite surface there is a square hole 2.9-16x4.9-16, ⅛ inch deep to receive the end of a brick. The weight pieces naturally must be just twice the weight needed for the test as half the weight is supported by the kiln wall. (See accompanying diagram).

A member of this society in discussing this stated that he thought it would be a better plan to bring to bear a sudden definite weight upon the tile by means of a sliding weight on a scale beam acting through a rod from the outside after raising to the required temperature. I see an objection to this plan in that a clay will change its shape but very slowly under pressure. This might be understood if we compare it to a piece of ice, if say, a cubic inch of ice were placed in a chamber just at the freezing point. Supposing a heavy weight was placed upon it for thirty seconds, this weight, while very heavy, not to be so great as to make it change its shape. Supposing again a very light weight, say only 1-10 of the weight just used, were then placed upon it and allowed to remain for several hours. What would be the result ? Would not the lighter weight be found to have made a decided change in the shape of the ice ? This same condition might be found to apply to clay.

Under my test a three hour load of 15 lbs. at high temperatures would have a decided effect upon a certain sample, while a 50 or 60 lb. weight for 30 seconds would hardly show any change of shape.

These experiments, in my style of furnace would offer a fair indication of the action of clays under stress while the sudden load might prove very misleading. This is however a surmise and may not prove true in practice.

DISCUSSION.

Mr. Gorsline: Does your paper show the difference in composition of the different samples ?

Mr. Parker: No.

Mr. Binns: What do you think is the maximum load per square inch it is desirable to apply ?

Mr. Parker: Ordinary mixtures ought not to carry over five pounds per square inch.

Mr. Binns: What is the maximum load necessary to apply in the matter of tests ? The little post is a square inch section, and you have on the diagram fifty pounds; is that the maximum load you think desirable to apply in the test ?

Mr. Parker: Yes, sir. I do not think fire brick would ever have to undergo a more severe test.

Mr. Wheeler: We are certainly indebted to Mr. Parker for starting a new line of investigation. Engineers of the past have been merely guessing. They thought and hoped brick would carry certain loads they were expected to carry, but they never had any definite data. I hope Mr. Parker will carry this investigation further and I know it will be an extremely valuable paper to the entire engineering profession.

I would like to ask whether in the material he has been working on, ten pounds load to the square inch would be equivalent to about an eleven foot solid column. Would a load of ten pounds on the square inch be the actual equivalent of a column about eleven feet high ?

Mr. Parker: I do not know.

Mr. Wheeler: Do you know the specific gravity of the material ?

Mr. Parker: No. I only know that the actual weight is 121 pounds to the cubic foot.

Mr. Wheeler: That will be pretty close to a ten foot column. You say after shrinkage over a certain amount, you considered it a failure ?

Mr. Parker: That is the only way I could do. This (referring to model) is too tall for a good test, it is liable

to bend, and it would be better to have it more the shape of a brick, probably a brick cut off.

Mr. Binns: If you had that, would it not require an enormous load in the kiln to crush it ?

Mr. Parker: Yes.

Mr. Wheeler: The temperature surrounding these tests is determined how ? Are they cone degrees or Le Chatelier degrees ?

Mr. Parker: Both. We have the general temperature of the kiln and each test is surrounded by a number of cones that we expect to go to.

Mr. Wheeler: What kind of a fracture is it, a vitrified fracture ?

Mr. Parker: If we have a heavy load we will not get it, but find it if we have a light load.

Mr. Wheeler: If it passed the limit of success, it would show a vitreous fracture ?

Mr. Parker: Yes. None of the tests in use are supposed to go over 2800° ; but we go higher than that.

Mr. Wheeler: I think Mr. Parker has used an extremely severe test. The substitution of the brick will be far more valuable to us, but he clearly brings out the information he is seeking.

Mr. Binns: The load is established before the kiln is lit ?

Mr. Parker: Yes.

Mr. Binns: No attempt is made to increase the load in the kiln ?

Mr. Parker: No. We establish it before. We have a half dozen samples with different weights. We bring the kiln up till we note the first failure; then stop the kiln and take our measurements. Then the next time we go perhaps fifty degrees higher with the same material in the kiln. We make two or three tests that way. Of course, it takes a long time.

Mr. Wheeler: What is the size of the kiln ?

Mr. Parker: It is only a little kiln which will hold six samples under load and three without load. We found in a number of instances when we had two and a half, five,

and seven and a half pound loads that the depreciation seemed to be accordingly. In 2½ pounds we had a depreciation of .13 inch; 5 pounds, .24 inch; 7½ pounds; .48 inch; and so it progressed. These tests lasted 24 hours only.

Mr. Geijsbeek: What kind of fuel was used ?

Mr. Parker: Oil.

Mr. Stover: I think this is the beginning of a series of trials for the sagger question. I believe by having all the trials alongside of the wall you come nearer getting the same condition of kiln atmosphere. I believe it can be done in various parts of the kiln and then you can determine the conditions of certain tests in certain heats under certain loads in various parts of the kiln. It would certainly be valuable data for sagger men.

STRENGTH OF SAGGER BODIES.

BY

L. E. Barringer, Schenectady, N. Y.

Mr. Parker's paper on the testing of refractories under load and temperature conditions, recalls some experiments made by the writer on sagger bodies in order to compare their fitness for bearing loads under a cone 11 fire. The saggers were to stand the weight of heavy porcelain insulators of the oil-switch type. The tests were made cold, but it was found that, in general, the strongest bodies cold were the strongest hot, providing no considerable amount of clay was used in the mixture which would vitrify and soften under the heat to which the saggers were subjected. The mixtures experimented upon were as follows, the proportions being by volume:

No. 1.	7 parts Edgar's No. 10 black sagger clay.	
	15 parts Akron ground fire clay.	
	22 parts coarse grog.	
No. 2.	7 parts Such clay (BB mixture).	
	15 parts Akron clay.	
	22 parts coarse grog.	
No. 3.	7 parts No. 1 buff sagger clay.	Edgar's.
	7 parts No. 10 black sagger clay.	
	12 parts coarse grog.	
No. 8.	2 parts Crosman's No. 1 clay.	
	1 part coarse grog.	
No. 9.	3 parts red spotted clay.	Clays from McHose, Perth Amboy, N. J.
	2 parts universal clay.	
	1 part sandy blue clay.	
	4 parts coarse grog.	
No. 15.	9 parts Akron Ground Clay.	
	2 parts N. J. Ball Clay.	
	9 parts coarse grog.	
No. 18.	15 parts Akron Clay.	
	7 parts McHose red spotted clay.	
	6 parts grog to 7 parts clay mixture.	

The clays in all cases were put through a 20 mesh sieve. The grog used had been ground in a dry pan with

¼″ screen plates, and all grog finer than would lodge on a 16 mesh sieve was rejected. Clays and grog were measured out by volume, mixed, made into a stiff mud and molded into briquettes in plaster molds and carefully dried.

Briquettes were also made of the individual clays in order to note their qualities. The dried briquettes were all burned together (placed on edge in a sagger and set about 10 high) in a biscuit kiln, to cone 11. The burned briquettes were then subjected to crushing and cross-breaking tests, the shrinkage first being measured. The results were as follows:

No.	Shrinkage	Breaking strain	Crushing strain
1	3.4%	No test	3625
2	2.2	165	2900
3	3.9	143	2175
6	3.0	140	2175
8	5.1	125	2175
9	3.1	150	2900
15	2.2	190	3262
18	4.0	210	4350

The shrinkage in each case was obtained by taking the mean of two briquettes, measured after firing, and comparing this with the mold dimensions.

The cross-breaking strain was determined on an Olsen machine, using briquettes measuring approximately 2⅝ x 5″ x 1″. The figures are for the whole briquette in each case. The comparative crushing strain was not determined on cube sections, but on the whole briquette placed on edge, the briquettes measuring 3″x 5″x 1″, and the test being made on a hydraulic press. The figures are for the whole briquette in each case.

It will be noted that Nos. 1, 15 and 18 give the best figures. While no test was secured on No. 1 in cross-breaking, owing to defective briquettes, it may safely be assumed high, as the strength varies approximately with the crushing strain, as shown in the other samples.

On making 12″ circular slabs of the mixtures and firing with loaded porcelain, Nos. 1 and 18 gave the best results in not sagging nor cracking in six burns. There was not much difference in the two.

BONE CHINA BODIES.

BY

ARTHUR S. WATTS, Victor, N. Y.

For several years past the writer has been associated with porcelain in its various forms and uses. He has been connected with the manufacture of the cones produced by Prof. Orton, the china ware produced by one of our white ware potteries, and insulators for high potentials in two plants. In all of these positions his work has been with the body and glaze materials. Ever since his early college days the role of lime, as displayed in the cones from 4 up, has been a fascinating study to him. The enormous amounts of calcium phosphate which the English have succeeded in using successfully, have led him to feel that there must certainly be some combination in which we can use this material, and produce the beauty of the famous Staffordshire ware without the enormous losses which all manufacturers of bone china are understood to suffer.

Before starting a study of bone china I thought it best to ascertain the correct definitions of this body from Prof. Orton and Prof. Binns, outside of that obtained from a study of the chemical formulae of such bone-chinas as I had. In reply to my inquiry Prof. Orton stated that his conception of a bone china is "a body chiefly composed of clay substance and chiefly fluxed with calcium phosphate. It may contain small quantities of flint, spar or Cornish stone but, as I understand it, no one of these materials is a "sine qua non." Prof. Orton further states that until the calcium phosphate exceeds 20% he does not consider the body entitled to the name "bone china." Prof. Binns says: "I have no "definition" for bone china. The composition covers it. A content of 40% of bone ash is a fair average, and this must not vary greatly." I also took the liberty to write to our former president, Mr. Ernest Mayer, for such information as he felt inclined to offer, and wish

here to express my appreciation of the generous manner in which he replied. He says "My definition of bone china would be a body containing bone in variable proportions, and as the Staffordshire bodies contain from 45 to 50% of bone I think the term bone china is generally used to distinguish it from the French or German acid porcelains, which, as you know, contain no bone."

Mr. Mayer follows by giving the composition of two Staffordshire bodies which he knows have been successfully used, and which are included in the list which will follow. We further find in Vol. I, Transactions of the North Staffordshire Ceramic Society, the following opinions on the role played by bone ash in English china bodies. Mr. Arnoux says: "There is this peculiarity about bone chinas, that the phosphate of lime entering into their composition is not decomposed by the silicates, with which it is mixed, and as practically it is infusible, its admixture in the body allows the ware to stand without injury at a temperature at which the feldspathic constituents of the body melt. Salvetat says: "Phosphate of lime, admixed in small proportions, adds to the fusibility of feldspar." Dr. Watkin concluded from experiments made at Burslem some years ago that, if *added in small proportions,* phosphate of lime added to the fusibility of clays and marl.

Bourry classes phosphate of lime as a flux.

Mr. Binns says: "Some writers state that bone acts as a flux, but this it not the case. Calcium phosphate is practically infusible, and there is no doubt that its function in a body is to uphold the mixture and to enable it to endure a more severe fire than it would otherwise do." Mr. H. E. Wood, in discussing these opinions, says: "If calcium phosphate were a flux we should get nothing but a glass from our saggers, as the stone in the body is of itself sufficient to give translucency at the same temperature. A large portion of bone, however, does not interfere with this translucency, but instead appears to slightly increase it. This may be only apparent, however, and due to the increased whiteness caused by the addition of bone If the increase of translucency is real, it may be explained

by the small proportion of lime which exists in all bone ash as calcium carbonate. Mr. Wood in conclusion says: "Phosphate of lime introduced by means of bone remains phosphate of lime throughout the firing, and merely dissolves in the silicates present without interfering with their translucency."

Mr. A. Heath said that from experiments, at Tunstall, calcium phosphate, when present in china bodies in large amounts, is a powerful flux. He obtained the following results:

Body without	bone, contraction	10.0%,	blisters badly.
Body with 5%	bone, contraction	6.2%.	
Body with 10%	bone, contraction	8.0%.	
Body with 20%	bone, contraction	8.0%.	
Body with 30%	bone, contraction	8.5%.	
Body with 40%	bone, contraction	9.0%,	starts to blister.
Body with 50%	bone, contraction	10.0%,	blisters badly.

With such a variety of opinions as the writer has just recited, one would dare to make almost any assertion he pleased on the subject of bone china, knowing that he could find some statement to verify his assertion.

However, I am trying to find some data that will assist me and serve as a nucleus for research, and I find here only a series of contradictions, which lead me to conclude that among our English co-workers, whose especial property bone china is, there exists either a woeful lack of knowledge on the subject, or a disinclination to impart the knowledge they have.

I concluded, therefore, to study first the bone china bodies of which I knew the composition, in order to determine whether any clue as to the variation in composition which exists in practical bone chinas might be traced down. The writer regrets that he did not have a larger list at his disposal, but had to do the best he could with the compositions available.

List of Bone China Bodies.

0.080 K_2O	1 Al_2O_3	3.200 SiO_2	English Bone China.
1.756 CaO		0.585 P_2O_5	Page 92, Vol. IV
1.836			Trans. A. C. S.

0.220 K_2O 2.170 CaO 2.390	1 Al_2O_3	4.45 SiO_2 0.72 P_2O_5	Amer. Bone China. No. 2 very fine.
0.215 K_2O 2.210 CaO 2.425	1 Al_2O_3	4.68 SiO_2 0.74 P_2O_5	English Bone China. Unknown make.
0.192 K_2O 2.487 CaO 2.679	1 Al_2O_3	2.770 SiO_2 0.829 P_2O_5	Bone China Body. Contributed by Ernest Mayer.
0.269 K_2O 2.540 CaO 2.809	1 Al_2O_3	3.39 SiO_2 1.67 P_2O_5	Modern English Body Vol. III Trans.A.C.S.
0.159 K_2O 2.566 CaO 2.814	1 Al_2O_3	4.53 SiO_2 0.885 P_2O_5	Amer. Bone China No. 3.
0.137 K_2O 2.737 CaO 2.874	1 Al_2O_3	4.25 SiO_2 1.09 P_2O_5	Body of English Porc. Vol. III Trans.A.C.S.
0.180 K_2O 2.790 CaO 2.970	1 Al_2O_3	3.03 SiO_2 0.93 P_2O_5	Amer. Bone China No. 1.
0.1054 K_2O 3.1690 CaO 3.2744	1 Al_2O_3	3.580 SiO_2 1.056 P_2O_5	Bone China Body Contributed by Ernest Mayer.
0.230 K_2O 5.200 CaO 5.430	1 Al_2O_3	7.12 SiO_2 1.50 P_2O_5	Body English Porc. Vol. III Trans.A.C.S.

A study of these bodies led the writer to presume that the limits within which we may expect to make good bone chinas are not so narrow as some would have us think. The RO varies from 1.836 to 3.2 in modern china, the K_2O from .08 to .269, and the SiO_2 from 2.77 to 4.68. Nor does high potash appear to call for low silica, as is often the case in acid porcelains. I found so little to guide me that I decided to take up the study in an entirely different way and shall first try to settle the question, "Does bone ash act as a flux?" by a series of trials, in which I shall begin with a good porcelain body and add bone ash, noting the results.

*I shall take the formula B-III-E (Vol. IV, Trans. A. C. S., page 100).

$$\left.\begin{array}{l}0.3\ K_2O\\0.2\ CaO\end{array}\right\}1\ Al_2O_3 \qquad 5.2\ SiO_2$$

This is a good porcelain at cone 9, with fine translucency and as high in lime as is practical. Tri-calcium phosphate, $Ca_3\ (PO_4)_2$ was substituted for the calcium carbonate in the mixture, and the following series was made:

Series D-I.

D-I- 1	0.30 K_2O 0.20 CaO	1 Al_2O_3	5.200 SiO_2 0.066 P_2O_5
D-I- 2	0.30 K_2O 0.30 CaO	1 Al_2O_3	5.200 SiO_2 0.100 P_2O_5
D-I- 3	0.30 K_2O 0.35 CaO	1 Al_2O_3	5.200 SiO_2 0.117 P_2O_5
D-I- 4	0.30 K_2O 0.40 CaO	1 Al_2O_3	5.200 SiO_2 0.133 P_2O_5
D-I- 5	0.30 K_2O 0.45 CaO	1 Al_2O_3	5.200 SiO_2 0.150 P_2O_5
D-I- 6	0.30 K_2O 0.50 CaO	1 Al_2O_3	5.200 SiO_2 0.167 P_2O_5
D-I- 7	0.30 K_2O 0.55 CaO	1 Al_2O_3	5.200 SiO_2 0.183 P_2O_5
D-I- 8	0.30 K_2O 0.60 CaO	1 Al_2O_3	5.200 SiO_2 0.200 P_2O_5
D-I- 9	0.30 K_2O 0.70 CaO	1 Al_2O_3	5.200 SiO_2 0.233 P_2O_5
D-I-10	0.30 K_2O 0.80 CaO	1 Al_2O_3	5.200 SiO_2 0.267 P_2O_5
D-I-11	0.30 K_2O 1.00 CaO	1 Al_2O_3	5.200 SiO_2 0.333 P_5O_2
D-I-12	0.30 K_2O 1.20 CaO	1 Al_2O_3	5.200 SiO_2 0.400 P_2O_5

* In all this work I shall use only such materials as we use commercially in potteries. My flint, feldspar and clays are all American materials taken from regular stock and my bone ash is a supply obtained from a first class ceramic supply house. The trials are all ground in wet ball mills for two hours and then put through 120 mesh brass screens.

This series was made up and fired first at cone 6, in order to note whether any fluxing action is apparent at this low temperature.

Series D at Cone 6.

D-I-1. Quite translucent and of a fine close structure, but quite blue in color. Quite smooth on the surface and undoubtedly sufficiently matured for all practical purposes.

D-I-2. Less translucent than preceding specimen but a good, dense, semi-translucent porcelain, quite blue but of fine texture.

D-I-3. Little evidence of translucency in this specimen, but otherwise it is a fine hard body.

D-I-4. No translucency but undoubtedly thoroughly vitrified and very strong. Quite blue.

D-I-5. Not translucent but a good dense vitrified body that, although quite blue, shows its hardness and strength on the surface.

D-I-6. Apparently about the same as D-I-5.

D-I-7. Same as D-I-5.

D-I-8. Good hard, blue, stony, body.

D-I-9. Hard stony body, but not so blue as preceding specimens.

D-I-10. Same as D-I-9 but more of a yellowish cast.

D-I-11. Hard, vitreous porcelain, not translucent but very dense, of a decided creamy tint.

D-I-12. Good vitreous body but not translucent, very yellow color for so vitreous a piece of ware.

Conclusions on Series D-I at Cone 6.

We have here evidently a graduated series, but it appears that the bone ash, either owing to quantity or temperature, does not act as a flux in this series, at cone 6.

The same series was now fired at cone 8, and the results noted.

Results of Cone 8 firing on Series D.

D-I-1 shows plenty of maturity even at this temperature, being quite translucent, but quite blue. It appears to be of slightly stony structure.

D-I-2 shows about the same degree of maturity as does D-I-1, but has lost the trace of stoniness and seems to be slightly more translucent.

D-I-3 seems to be free from any trace of stoniness and even appears slightly glassy. A slight improvement over D-I-1 and 2 as regards color is noted.

D-I-4 shows a decided improvement over the lower numbers so far as color is concerned, being only slightly blue, but a tendency to lose shape is observed.

D-I-5 shows a very fair white color, but even more of a tendency to warp than does D-I-4.

D-I-6 shows about the same tendency to warp as the last two numbers, but shows an improvement in color.

D-I-7 shows a marked tendency to warp, but gives evidence of a good color.

D-I-8 is a good white color but badly warped.

D-I-9 shows a tendency to creaminess in color. Owing to its shape, which is different from the rest of the series, I cannot judge of its tendency to warp. It is quite translucent.

D-I-10 shows a decided creamy tint, but is warped as badly as any of the preceding. I note an improvement in translucency over any of the preceding numbers.

D-I-11 is very badly warped and settled. However, it shows a very notable improvement in translucency but is quite yellow in color.

D-I-12 from its position in the sagger was especially favored and did not warp so badly as the preceding number, but its appearance would indicate that under the same conditions it would warp as badly or worse than any of the others.

Conclusion, at Cone 8, on Series D.

Series D-I convinces me that from 0.3 potash, 0.2 lime to 0.3 potash, 1.2 lime, the calcium being introduced as

Bottom row of trials fired at cone 6, middle row at cone 8, and top row at cone 10.

bone ash, there is a softening tendency displayed as the series progresses from No. 1 to No. 12. There is also a gradual and very distinct graduation from the blue white in D-I-1 through the cream white of No. 8 and No. 9, to the decided cream color of No. 11 and No. 12. Also, the translucency increased as the proportion of calcium phosphate increases.

This series was then fired at cone 10 and the effect noted.

Series D-I at Cone 10.

D-I-1 shows a very slight tendency to warp, even under pressure, but otherwise shows but little more evidence of maturity than at cone 8. It is slightly less blue than at the lower heat, and possibly a trifle more translucent.

D-I-2 shows a notable tendency to warp whenever the other trials leaned against it. About the same color and translucency as D-I-1.

D-I-3 shows a tendency to warp and also to settle. Somewhat whiter than either 1 or 2.

D-I-4 warped and settled considerably.

D-I-5 warped and settled slightly worse than D-I-4, evidencing by its position that it began to warp and lean before D-I-4.

D-I-6, although so placed that it could not lean, has settled to ⅔ its original height. Its color is a good cream and very noticeable against the bluish cast of D-I-1 and 2. Translucency somewhat improved.

D-I-7 has settled slightly in advance of D-I-6, as shown by its position. Color a good white.

D-I-8 settled slightly worse than D-I-7 and in advance of it, as its position shows: slightly translucent where thin. Color good white.

D-I-9, placed so that it could not lean, but has settled to ½ its original height. It begins to show a marked yellow tint.

D-I-10 settled as badly as D-I-9 and was of about the same color. Slightly translucent.

D-I-11 settled even worse than D-I-10, and shows a decided yellow color.

D-I-12 shows about the same amount of warping as the preceding number, but shows more translucency than any of the others.

Conclusions on Series D, at Cone 10.

The results at cone 10 confirm the cone 8 observations, i. e., as the bone ash increased in percent the body showed a decided tendency to grow softer and whiter, reaching its maximum whiteness at D-I-8, 0.3 K_2O, 0.6 CaO, or D-I-9, 0.3 K_2O, 0.7 CaO, after which it became more yellow as the amount of phosphate increased.

It is evident that more potash is present than is needed, since its fluxing effect is evident even in the cone 8 fire. Hence the R_2O of the series will be reduced one-third. and, beginning with 0.2 potash and 0.8 lime as flux, another series, E, will be made, using the same alumina and silica as in Series D, and increasing the calcium phosphate.

Series E-I.

E-I- 1	0.2 K_2O 0.8 CaO	1 Al_2O_3	5.200 SiO_2 0.267 P_2O_5
E-I- 2	0.2 K_2O 0.9 CaO	1 Al_2O_3	5.200 SiO_2 0.300 P_2O_5
E-I- 3	0.2 K_2O 1.0 CaO	1 Al_2O_3	5.200 SiO_2 0.330 P_2O_5
E-I- 4	0.2 K_2O 1.1 CaO	1 Al_2O_3	5.200 SiO_2 0.367 P_2O_5
E-I- 5	0.2 K_2O 1.2 CaO	1 Al_2O_3	5.200 SiO_2 0.400 P_2O_5
E-I- 6	0.2 K_2O 1.3 CaO	1 Al_2O_3	5.200 SiO_2 0.433 P_2O_5
E-I- 7	0.2 K_2O 1.4 CaO	1 Al_2O_3	5.200 SiO_2 0.467 P_2O_5
E-I- 8	0.2 K_2O 1.5 CaO	1 Al_2O_3	5.200 SiO_2 0.500 P_2O_5
E-I- 9	0.2 K_2O 1.6 CaO	1 Al_2O_3	5.200 SiO_2 0.533 P_2O_5

E-I-10	0.2 K_2O 1.7 CaO	}	1 Al_2O_3	{ 5.200 SiO_2 0.567 P_2O_5
E-I-11	0.2 K_2O 1.8 CaO	}	1 Al_2O_3	{ 5.200 SiO_2 0.600 P_2O_5

Results on Series E-I, at Cone 4.

This series was fired at cone 4, and even at this temperature the following results were obtained:

E-I-1, quite noticeably translucent.

E-I-2 shows some translucency.

E-I-3 fails to show any translucency, and the remainder of the series is good hard biscuit, which steel will barely scratch.

Neither E-I-1 or 2 show any evidence of maturity on the surface, and would easily pass for good hard biscuit unless they are held to the light, when their translucency is easily noted.

Results on Series E-I, Cone 8.

E-I-1 shows a strong tendency to sag and warp, and is of that peculiar color common to overfired bone china. Quite translucent.

E-I-2 is little better than the preceding specimen, being badly warped and off in color. Good translucency.

E-I-3 is not quite so badly warped as the two preceding specimens but the specimen is thicker so that may account for it, as also the fact that it found a support in another higher specimen, which perhaps prevented its sagging so badly as it otherwise would have done. Translucency not so good.

E-I-4 is not so badly warped but is twisted out of its original form somewhat, and while somewhat whiter than the preceding specimens, is by no means white. Little translucency.

E-I-5 is slightly warped, but of notably better color than the lower numbers. Little translucency.

E-I-6 shows a slight improvement in color, but is little better so far as warping is concerned.

E-I-7 is quite white, but is also slightly warped and has a milky hue with little translucency.

E-I-8 shows a very good white color, and, even though it is unusually thin, is warped no worse than the specimens preceding it. It shows more translucency than the preceding two or three numbers.

E-I-9 shows some improvement over the preceding numbers but is still over matured, although it was so placed that it did not warp.

E-I-10 is a good specimen showing only a trifle of overfiring, while it is perfectly true and has not warped or twisted in the least. It shows some translucency, although not what is demanded in good bone china, yet it is a fair specimen of bone china.

E-I-11 is a good specimen of bone china, not warped at all, and has some translucency but not so much as is desired. Color good, but a cast of yellow in a few pieces that writer cannot explain.

Conclusions on Series E-I, at Cone 8.

It is to be regretted that the temperature in this test ran a trifle high, so that the test is nearer cone 9 than cone 8. It seems, however, to show that within the range of this series, bone ash, tri-calcium phosphate, reaches its maximum fluxing power and begins its decline toward its commonly acknowledged sphere of a non-flux.

Results on Series E-I, Cone 10.

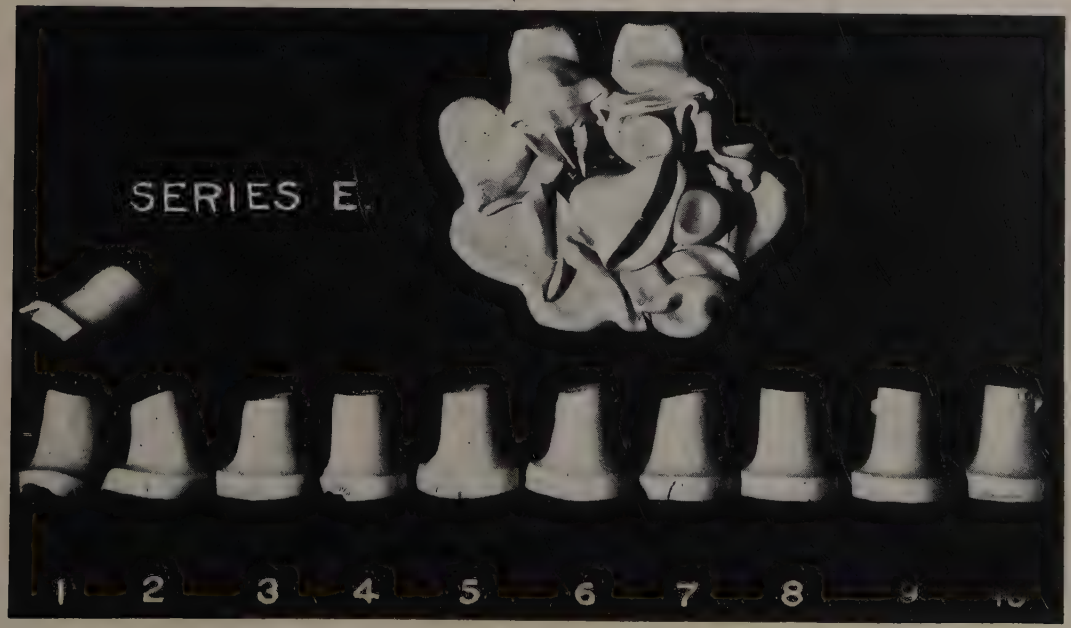
This entire series has collapsed at cone 10, only the highest numbers retaining any resemblance to their former shapes.

E-I-1 shows a degree of softness about equal to a No. 8 cone which has been fired at cone 9, and from its position must have collapsed before any of the other trials.

E-I-2, E-I-3, E-I-4 and E-I-5 show by their positions that they went down in regular order.

E-I-6 collapsed also, but its surface and shape do not indicate such complete fusion as the preceding numbers.

E-I-7 settled about the same time as E-I-6, but its



Row of trials fired at cone 8, partially fused trials at cone 10.

surface does not indicate so much fusion, and it has more of the appearance of a zinc enamel than any of the lower numbers, which all show a resemblance to an under matured lime glaze.

E-I-8 shows more of the dead appearance than the preceding numbers, and is not so completely collapsed.

E-I-9 has only collapsed to about ½ its original height, and shows decidedly less fusion than any of the lower numbers.

E-I-10 shows about the same degree of fusion as E-I-9, but has a notable color common to bone china.

E-I-11 retained its general shape but was sagged and distorted. It has the typical color of bone china and the same zinc white color on the surface. However, its surface has a trace of glassiness which is not found in bone china.

Conclusions on Series E-I, at Cone 10.

This series shows very clearly the fluxing power of tri-calcium phosphate, especially when studied in connection with series D. When one first compares E-I-1 and D-I-12, one is struck by the fact that E-I-2 containing less flux is apparently the softer, but the writer sees, at a second glance, that in reducing the amount of potash the amount of feldspar added is reduced and hence, to maintain the same amount of silica, a larger amount of flint must be used, and also it is noted that D-I-12 contains, by weight, over 40% more of calcium phosphate than does E-I-1. It is evident from Series E-I that the calcium phosphate begins to act as a non-flux in this series, and I note that E-I-6 contains about the same per cent, by weight of phosphate as does D-I-12, but has 20% more free silica in its composition. Its surface is perhaps a trifle softer, but the two specimens are generally the same in color and texture. I am convinced that 5.2 silica is more than can be successfully used in a bone china body, so I reduced the next series to 4.2 silica and continued increasing the tri-calcium phosphate.

Series F-I.

F-I- 1	0.2 K_2O 1.8 CaO	1 Al_2O_3	4.200 SiO_2 0.600 P_2O_5
F-I- 2	0.2 K_2O 1.9 CaO	1 Al_2O_3	4.200 SiO_2 0.633 P_2O_5
F-I- 3	0.2 K_2O 2.0 CaO	1 Al_2O_3	4.200 SiO_2 0.667 P_2O_5
F-I- 4	0.2 K_2O 2.1 CaO	1 Al_2O_3	4.200 SiO_2 0.700 P_2O_5
F-I- 5	0.2 K_2O 2.2 CaO	1 Al_2O_3	4.200 SiO_2 0.733 P_2O_5
F-I- 6	0.2 K_2O 2.3 CaO	1 Al_2O_3	4.200 SiO_2 0.767 P_2O_5
F-I- 7	0.2 K_2O 2.4 CaO	1 Al_2O_3	4.200 SiO_2 0.800 P_2O_5
F-I- 8	0.2 K_2O 2.5 CaO	1 Al_2O_3	4.200 SiO_2 0.833 P_2O_5
F-I- 9	0.2 K_2O 2.6 CaO	1 Al_2O_3	4.200 SiO_2 0.867 P_2O_5
F-I-10	0.2 K_2O 2.7 CaO	1 Al_2O_3	4.200 SiO_2 0.900 P_2O_5
F-I-11	0.2 K_2O 2.8 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5

Series F-I, at Cone 6.

At cone 6 this series shows only a good chalky appearance, and can be cut with a hard steel point.

Series F-I, at Cone 8.

F-I-1. This is as perfect a specimen of bone china as the writer ever saw, showing fine translucency, beautiful, soft appearing surface, but a faint yellow tint is noted. No warping.

F-I-2 is fully as translucent as F-I-1, and has about the same surface appearance. Its color is improved. Little or no yellow cast being noted.

F-I-3 is all that can be asked. Maximum translucency, fine surface, perfect white color.

F-I-4 is equal to F-I-3. There is no choice.

Bottom row of trials fired at cone 8, second row at cone 10, top trials at cone 14.

F-I-5 is as good as the two preceding, so that no criticism can be made on it.

F-I-6 is another beautiful specimen, perfect in every way.

F-I-7 is a splendid bone china. I note a slight trace of hardness in the appearance of this specimen which I have not noted in the other specimens.

F-I-8 is equal to the preceding specimens, but there is noted the same appearance of hardness as in F-I-7.

F-I-9 is also a splendid specimen, but it is noted that its translucency is not so distinctly of the bone china color, being slightly more like that of acid porcelain, due, the writer thinks, to the harder appearance of the surface. I do not mean by this that the specimen indicates harder firing.

F-I-10, although very thick, is exceedingly translucent, and possesses all the qualities of a bone china. Its surface and translucency is similar to F-I-9.

F-I-11, similar to F-I-10, and fully equal to any of this series in translucency and color.

Conclusions on Series F-I, at Cone 8.

This entire series includes beautiful bone chinas at cone 8, and it is exceedingly difficult to choose any particular specimen as a favorite. In comparing F-I-1 and F-I-11, a notable difference in the texture of the surface is found. F-I-1 is soft while F-I-11 has a hard, extremely smooth surface. I imagine I can trace the gradation of this quality from one end of the series to the other, though this may only be deception.

Series F-I, at Cone 10.

F-I-1 shows a splendid snow white color, with a slight greenish tint similar to that produced by a very small quantity of copper added to a white enamel. It is highly translucent and has none of the yellow tint so common with the American porcelain made from iron bearing clays. No evidence of warping or settling out of shape.

F-I-2 is a splendid specimen of bone china, being snow

white with perhaps a trifle more of the greenish hue. This, however, is doubtful, as I cannot find any one else who confirms this observation. Of this I am certain, that it is a perfect specimen of bone china, with splendid translucency and no evidence of warping or settling.

F-I-3 is another splendid specimen of china. It is completely beyond the power of the writer to decide which is superior in appearance. I can detect no evidence of warping in this specimen, but think that possibly it is less translucent than the two preceding specimens.

F-I-4 is equal to the preceding specimens in every way except that I think it has not quite the translucency of F-I-1 and 2.

F-I-5 is apparently about the same as the preceding specimen. In fact, it is equal in every way to any specimen of bone china the writer ever saw save in the matter of translucency, and in this respect its position would not be far behind the best.

F-I-6 is a fine white china, but one begins to detect in this specimen a trace of chalkiness.

F-I-7 is also a fine specimen, but has not the satin-like surface observed in the lower numbers. No evidence of warping.

F-I-8. This is a perfect bone china, pure white, no evidence of warping, has a fine soft surface, and while it is not quite so translucent as the lower numbers, it has enough translucency to satisfy most demands.

F-I-9 is perfectly white, but it is readily seen that the satin-like surface noted in the lower numbers has partly disappeared, leaving the chalky appearance noted in No. 6 and No. 7 quite prominent.

F-I-10 is notable for the fact that while hard and exceedingly white it has very little evidence of translucency, and the greenish tint noted in the lower numbers has almost completely disappeared.

F-I-11 is a good white bone china, but with a trace of greenish tint, a trace of translucency and a smooth hard surface, practically free from any trace of gloss. In fact, there is a distinct leaning to chalkiness in the surface ap-

pearance which I would not expect from a specimen showing translucency on exposed and thin parts as the specimen does.

Conclusions on Series F-I, at Cone 10.

It is evident from a study of this series that the maximum translucency is near the low end of this series, and I also believe that the most intense white is obtained below F-I-9.

While F-I-6, F-I-7 and F-I-8 are splendid specimens, they lack the glossy, satin-like surface shown in the lower numbers, and also the degree of translucency which the first five numbers of the series show. As to whether there is danger of warping or losing shape the writer cannot say, since no evidence of any such behavior in any specimen of this series was noted at this temperature. However, three specimens of this series were then taken and fired at cone 12 in order to detect warping or settling at this higher temperature.

Series F-I, at Cone 12.

On taking three specimens: F-I-1, F-I-6 and F-I-11, they were found to flatten at cone 12 about 50 per cent. F-I-1 shows only a trifle more maturity than at cone 10, but I notice the placing sand stuck more tightly to the bottom than to the cone 10 specimen. Also, it seems that the translucency, while somewhat increased, has more of the glassy look than it had in the cone 10 specimen.

F-I-6 shows some increased maturity at cone 12, but no evidence of warping or losing its shape. I note, however, that it has more gloss and shine than the cone 10 specimen, and also an increase in the greenish tint.

F-I-11. This specimen at cone 12 shows a marked improvement over cone 10, but still does not show the translucency of the lower numbers of this series. However, it has a fine color and a noticeable gloss on its surface, at this heat. It seems that this specimen has matured faster than either F-I-1 or F-I-6, but cannot be certain of this.

These three specimens were again put in the kiln and

fired to a heat at which cone 12 is down flat, in order to see whether either of them would warp or lose shape.

Series F-I, at Cone 14.

In this experiment I have added an additional specimen, H-I-1, with the same composition as F-I-11 save that the potash is absent. This will determine just where the power of the flux exists.

The results at cone 14 are as follows:

H-I-1 has completely fused, lost all shape, and lies completely flattened out on the bottom of the sagger.

F-I-1 has also fused and flattened out completely on the bottom of the sagger.

F-I-6 is less fused than F-I-1, and while badly slagged shows that it is not as soft as the lower specimen.

F-I-11 shows notably less fusion than any of the others. In fact, it is only about half down. This indicates, I think conclusively, that the feldspar cannot be condemned at this temperature, but the fact that the trial containing no feldspar or potash has completely fused, while the one containing .2 K_2O has stood much more fire is a puzzle, especially since the lower numbers F-I-1 and F-I-6 show more fusion. A notable fact is that F-I-1 contains only 12% of flint, while H-I-1 contains nearly 20%. Can the silica present as flint affect the action of the $Ca_3(PO_4)_2$?

Conclusions on the Entire F-I Series.

The writer is convinced, from this series, burnt at cone 6 to cone 14, that with K_2O, 1 Al_2O_3 and 4.2 SiO_2 a good bone china can be obtained with any equivalent of $Ca_3(PO_4)_2$, from 1.8 to 2.8, although it is evident that the higher equivalent of bone ash makes a more stable compound. However, as it is evident that less translucency is obtained with the higher equivalent than with the lower, I feel inclined to assume that somewhere about the center of the series we will find the best commercial ware.

The fact that the specimens containing the lower amounts of free flint seem to be acted on least by the

Bottom row of trials fired at cone 8, middle row at cone 11 and top row at cone 13.

$Ca_3(PO_4)_2$, as a flux, is interesting, and the writer therefore decided to make up a series ranging from a body containing no free flint to one containing quite a large quantity, noting the result.

Series G-I.

G-I- 1	0.2 K_2O 2.8 CaO	1 Al_2O_3	2.800 SiO_2 0.933 P_2O_5
G-I- 2	0.2 K_2O 2.8 CaO	1 Al_2O_3	3.000 SiO_2 0.933 P_2O_5
G-I- 3	0.2 K_2O 2.8 CaO	1 Al_2O_3	3.200 SiO_2 0.933 P_2O_5
G-I- 4	0.2 K_2O 2.8 CaO	1 Al_2O_3	3.400 SiO_2 0.933 P_2O_5
G-I- 5	0.2 K_2O 2.8 CaO	1 Al_2O_3	3.600 SiO_2 0.933 P_2O_5
G-I- 6	0.2 K_2O 2.8 CaO	1 Al_2O_3	3.800 SiO_2 0.933 P_2O_5
G-I- 7	0.2 K_2O 2.8 CaO	1 Al_2O_3	4.000 SiO_2 0.933 P_2O_5
G-I- 8	0.2 K_2O 2.8 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5
G-I- 9	0.2 K_2O 2.8 CaO	1 Al_2O_3	4.400 SiO_2 0.933 P_2O_5
G-I-10	0.2 K_2O 2.8 CaO	1 Al_2O_3	4.800 SiO_2 0.933 P_2O_5
G-I-11	0.2 K_2O 2.8 CaO	1 Al_2O_3	5.200 SiO_2 0.933 P_2O_5

Series G-I at Cone 8.

(Cone 8 was only started in this test.)

G-I-1. This trial shows splendid translucency, a fair surface and good color. Surface, however, appears slightly dry.

G-I-2 is also a splendid specimen of bone china, and is satisfactory in every way. Fine translucency, good color and good surface appearance. Surface still dry.

G-I-3. This specimen is a fine piece of ware at this temperature. Good translucency, color and texture of surface.

G-I-4 shows fine translucency and color, but the surface begins to show a slight gloss which indicates that it is softer than the preceding numbers.

G-I-5, similar to G-I-4. Very fine specimen.

G-I-6, fine specimen in every way, but the surface shows that it is perceptably softer than G-I-4 and 5.

G-I-7 is a fine specimen, but I think there is less translucency than in the lower numbers.

G-I-8 is a good specimen of bone china in every way, but I can note the surface and translucency do not indicate the hardness of No. 1 and No. 2.

G-I-9, very similar to G-I-8 in every way.

G-I-10, good bone china in every way but I note that the soft appearance in the surface is more prominent than before.

G-I-11. This number shows a decided softer appearance than any of the preceding.

Conclusions on Series G-I at Cone 8.

There is no doubt that this series shows conclusively that the softness increases with the addition of SiO_2. The lower numbers of this series have a peculiar, hard appearance of surface which I do not find in any other specimens so far, and I believe that they also possess more translucency than any former trials made. Another burn of the same series was therefore made at cone 10, and the results noted.

Series G-I at Cone 11.

Unfortunately this series was fired with cone 10 completely down, so that cone 11 must certainly have been reached.

G-I-1. This trial is superb bone china, and the only change that I can note is a very slight improvement in color over the same body at cone 8, although I thought that specimen had perfect color.

G-I-2 is not apparently changed at all by the increase in heat from cone 8 to cone 11, but remains a perfect bone china.

G-I-3 shows little evidence of the higher temperature and as in the two preceding numbers, there is little if any change in color, which continues perfect.

G-I-4 is a splendid specimen of bone china in every way.

G-I-5 varies little if any from G-I-4, unless it might be that its surface has a softer look, which, however, is not sufficiently pronounced to be a certainty.

G-I-6 shows a softer surface than the lower numbers, otherwise the same.

G-I-7 shows a slight tendency to warp as evidence that it is softer. Surface and texture good, also good color.

G-I-8 shows surface and color good but also shows a slight tendency to warp at this temperature, not so translucent.

G-I-9 shows a positive tendency to warp, but its color remains fine. Its surface indicates its increased softness.

G-I-10 shows a decided tendency to warp, being very noticeably settled. Its color is good but the surface is too glossy.

G-I-11. This specimen shows pronounced warping and settling. Also I note the gradual gradation in color which had before escaped me from a snow white to a creamy white. Less translucency also.

Conclusions on Series G-I at Cone 11.

The role of flint in this series is very pronounced, as it is increased the ware becomes notably more soft and inclined to warp, and also less translucent.

Series G-I at Cone 13.

Cone 12 was down flat so it was assumed that cone 13 would have been reached.

G-I-1 remains a perfect, snow white, fine surfaced piece of ware, equal if not superior, to any specimen so far obtained. Its color and texture have not changed from cone 8 up, and it shows no tendency to warp or twist although a very thin trial.

G-I-2 may be described best as a duplicate of G-I-1 so far as the writer was able to determine.

G-I-3 is a superb bone china, but I can detect a very slight tendency to warp at this temperature.

G-I-4 shows a more pronounced tendency to warp than was noted in G-I-3.

G-I-5 is decidedly sagged and out of shape.

G-I-6 is warped even worse than G-I-5.

G-I-7 has settled out of shape.

G-I-8 is worse than G-I-7.

G-I-9 is collapsed.

G-I-10 has flattened out and shows quite a bright surface.

G-I-11 has self-glazed itself.

Conclusion on Series G-I, at Cone 13.

This test only confirms the tests at the lower temperatures and shows conclusively that as the equivalent of silica is increased the product is softened and the translucency reduced.

There is only one more question to decide. Can the equivalent of K_2O be varied or increased without affecting the product?

Series H-I.

H-I-1	0.20 K_2O 2.80 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5
H-I-2	0.05 K_2O 2.80 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5
H-I-3	0.10 K_2O 2.80 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5
H-I-4	0.15 K_2O 2.80 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5
H-I-5	0.20 K_2O 2.80 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5
H-I-6	0.25 K_2O 2.80 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5
H-I-7	0.30 K_2O 2.80 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5

Bottom row of trials fired at cone 7, middle row at cone 11, top row at cone 13.

H-I-8	0.35 K_2O 2.80 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5
H-I-9	0.40 K_2O 2.80 CaO	1 Al_2O_3	4.200 SiO_2 0.933 P_2O_5

Series H-I at Cone 7.

H-I-1 is a good hard biscuit, with no evidence of translucency and with a half baked appearance to its surface.

H-I-2 is a good bone china, perhaps showing less translucency than the specimens higher in K_2O, but of good color and surface texture.

H-I-3 is a fine, highly translucent, bone china body, with fine color and texture.

H-I-4 is very similar to H-I-3.

H-I-5 shows all the good qualities of those preceding it, and also has a harder look to its surface.

H-I-6 shows a fine translucency with good color, and a continuance of the hard dense look of H-I-5.

H-I-7, although very thick, shows an excellent translucency and a splendid color and texture.

H-I-8 is a fine bone china, equal to any so far produced.

H-I-9 is a perfect bone china body, and I doubt if it could be excelled at this temperature.

Conclusions on Series H-I, at Cone 7.

A study of this series at cone 7 shows that while H-I-1 is only a biscuit, we obtain, by adding .05 equivalent of K_2O a product that is almost, if not quite, the softest of the series. The entire series is of fine color and with no evidence of warping.

Series H-I, at Cone 11.

H-I-1 shows at this temperature a peculiar reddish translucency similar to that found in acid porcelain that is underfired but not so conspicuous.

H-I-2 is of good color but shows a very slight tendency to warp. Fairly translucent, but very yellowish in tint.

H-I-3 is similar to H-I-2, and I think shows as much or a little more warping tendency. Quite translucent and better color of translucency.

H-I-4 shows a tendency to warp, but not so pronounced as H-I-3. Translucency good.

H-I-5 gives us a good bone china body, no tendency to warp, fine color and good surface. Fine translucency.

H-I-6 is a fine specimen, translucency increased, and of fine color and surface.

H-I-7 has, I imagine, even more translucency than the preceding specimen, and is equally good in color and texture.

H-I-8 continues to improve in every way, I think.

H-I-9 is the choice specimen of the entire series, and is a superb specimen of bone china.

Conclusions on Series H-I, at Cone 11.

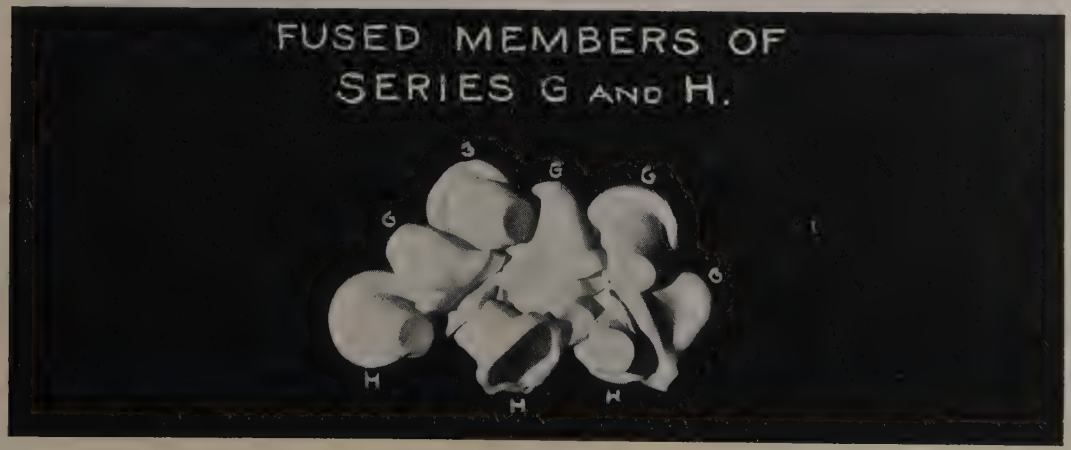
The conclusion which I reach from the study of this series is that with .05 K_2O one obtains the maximum fluxing power of the $Ca_3(PO_4)_2$. The addition of more K_2O seems to enable the body to stand without so much warping until up to 0.2 K_2O, when it seems to produce even a more stable compound.

However, study of this series brings before me again the fact that H-I-1 contains 19.5% flint, while H-I-9 contains only 5%. Again the power of flint to soften a bone china body confronts me. However, it seems to be unable to be active except in the presence of some potash.

As the potash is introduced in increasing equivalents the quality of translucency improves notably.

Conclusions on Series H-I, at Cone 13.

H-I-1 is completely collapsed.
H-I-2 is completely collapsed.
H-I-3 is completely collapsed.
H-I-4 is settled to ½ its height.
H-I-5 is settled to ½ its height.
H-I-6 is settled to about ⅔ its height.
H-I-7 is settled to about ⅔ its height.



Fired at cone 13.

H-I-8 has twisted bady and settled a trifle.

H-I-9 has twisted badly but, although badly hampered by others leaning on it, has not settled badly.

Conclusions on Series H, at Cone 13.

This temperature confirms the conclusion reached by lower temperature trials with but one exception. We now find that the $Ca_3(PO_4)_2$ behaves very much as does any lime composition.

Either this is the case or the P_2O_5 has volatilized, leaving only calcium oxide, and this has acted as it naturally would. The most important discovery in this series is, that with the addition of a small quantity of potash we get a softer product, while on increasing the potash the product becomes instantly harder. Even .05 potash has been proven sufficient to cause the $Ca_3(PO_4)_2$ to act as a flux, and to exert a gradual fluxing action similar to the action of potash in large quantity. Without this small quantity it does not act at all, at low temperatures.

We will now return to the object of this investigation. What are the limits in the composition of bone china?

What numerical values must be substituted in the general formula

$$\left.\begin{array}{l} w\ K_2O \\ x\ CaO \end{array}\right\}\ 1\ Al_2O_3 \left\{\begin{array}{l} y\ SiO_2 \\ z\ P_2O_5 \end{array}\right.$$

in which we have alumina equal to unity so that it is not a variable in this study of body composition.

Potash.

We have found that we can vary the K_2O with safety from .2 to .4, and perhaps higher, and can expect to obtain good bone chinas from cone 8 to cone 12, although we cannot go above cone 12 with 4.2 SiO_2. We cannot go below .2 K_2O, as we find that the body loses its shape.

Tri-Calcium Phosphate.

We have varied this constituent from .2 to 2.8, and find that within .2 to 1.2 $Ca_3(PO_4)_2$ when combined with .3 K_2O the $Ca_3(PO_4)_2$ acts as a flux with increasing power.

When the K_2O is reduced to .2 we find about 1.2 $Ca_3(PO_4)_2$ to show maximum fusibility, while above this, up to 1.8 $Ca_3(PO_4)_2$ we observe a hardening tendency.

From 1.8 to 2.8 $Ca_3(PO_4)_2$, when combined with .2 K_2O we get increased hardness, but as we approach the higher figures we find our translucency decreasing, so I think about the middle or .2 K_2O, 2.3 $Ca_3(PO_4)_2$ would produce the best commercial bone china with 4.2 SiO_2.

Silica.

Now we come to what I believe is the essential feature of bone china. In every series made, it is apparent that as the amount of flint or uncombined silica increases, the ability of the bone ash to act as a flux increases. There is no doubt but that the silica series G shows conclusively that increased silica means increased fusibility. This is especially notable in the series as well as the fact that with increased silica apparently decreased translucency results. It is to be especially noted that at cone 13, G-I-1, with no free flint in its composition, is a perfect bone china with no evidence of deterioration, while G-I-4, with 5.5% free flint, warps badly, yet both were good bone chinas at cone 8.

The writer concludes from his study of the subject, that bone china, for a range of from cone 8 to cone 12, can be made anywhere within the following limits:

$$\left.\begin{array}{l}0.2 \text{ to } 0.4\ K_2O \text{ or higher}\\ 1.8 \text{ to } 2.8\ CaO\end{array}\right\}\ 1.\ Al_2O_3 \left\{\begin{array}{l}2.8 \text{ to } 4.000\ SiO_2\\ 0.6 \text{ to } 0.933\ P_2O_5\end{array}\right.$$

DISCUSSION.

Mr. Stover: This is undoubtedly the most perfect attempt to show what each ingredient will do I ever heard of. I think Mr. Watts deserves much credit for the thorough manner in which he has taken up the subject. Is this a raw mix all the way through?

Mr. Watts: Yes; no fritting at all, no calcined bone was used. We did try calcining the bone, but found no improvement.

Mr. Stover: Has any of this porcelain been glazed?

Mr. Watts: No; none of the bodies were tried with a glaze.

Mr. Stover: In bone mixtures, with a highly silicious glaze on a low silica body, the latter will borrow some from the former.

Mr. Geijsbeek: Were the mixtures blunged or ground?

Mr. Watts: Ground in a ball mill.

Mr. Binns: It is evident that under some conditions, notably in the presence of flint, some disturbance of the phosphoric acid takes place. It is probably not expelled for we are aware how hard it is to dissipate, but that it effects a change of base I fully believe. Bone ash in small quantity has an effect similar to any other lime compound, when heated to a certain point it becomes, either entirely or partially, a silicate, with the usual phenomena of a white curd-like fusion. Safety is found, as Mr. Watts has shown, in an excess of bone and a limit in the matter of fire. Over-fired bone china exhibits a swollen, spongy structure pointing to an escape of gases, but what these gases might be I am unable to say.

Mr. Watts states that in his comparison of results he has ignored the alumina because it is constant. He forgets that in many instances he has drawn all of his alumina from feldspar, in others from feldspar and clay, and in others from clay alone. This, it seems to me, constitutes a variation in alumina, as I am quite sure that its behavior when drawn from clay is quite different than when drawn from other sources.

With these criticisms, I have only to thank Mr. Watts for his experiments, and I am quite confident we will see great help and important development come from the work he has done.

Mr. Geijsbeek: If Mr. Watts uses throughout the series chemical formulae with the alumina constant, but coming from spar or clay, the experiments are not conclusive.

Mr. Weelans: I will ask Mr. Watts what the duration of his fire was?

Mr. Watts: The duration of the fire was between forty-eight and fifty-two hours.

Mr. Purdy: The constancy of alumina in these series is not shown in the empirical formula, nor in percentage amounts, but it is nevertheless molecularly constant. It does make all the difference in the world from what source you derive your chemicals, whether you derive your alumina from clay, Cornwall stone, or feldspar. Mr. Coulter and I both showed that it did make a great difference whether the alumina was derived from Cornwall stone or feldspar. This is due entirely to the difference in the mineralogical character of the ingredients. I tried to make a similar point in the discussion of Mr. Hull's paper on chrome-tin pink. While not parallel to this, the case is akin.

We know if we mix lead and tin together we obtain tin ash. Physical chemists have told us they must be mixed in a definite ratio of lead to tin to get the most fusible mixture. The increase of either element above this proportion will decrease the fusibility of the mixture. This is only true where we have a solution. In a body you do not produce a homogenious fusion; it is more like a mineralogical mixture, while on the other hand the glaze approaches closer to a homogeneous solution. Yet we know that a glass or a glaze is not a definite silicate but a mixture of silicates. We know that in the silicates there can be dissolved phosphates and borates. I think Mr. Jackson and others have shown this in recent researches published in a recent issue of the Journal of the Society of the Chemical Industries. I think it can be proven that the phosphate desired from bone might very easily be retained in the body as calcium phosphate, or perhaps as a new phosphate compound. We cannot state definite facts until we have more analytical data, but I believe that we will find that phosphates can coexist with silicates and borates in one and the same solution, and that the fusion is caused by the formation of new phosphate and borate mixtures, as well as by the formation of new silicate compounds.

Mr. Geijsbeek: In chemical pottery formulae it is always advisable to take alumina as unity. Only when one alumina is quoted may we draw comparisons. Mr. Watts, therefore, did well to adopt this plan.

Mr. Burt: I would like to ask a question. It is a matter I do not know much about—bone china, but it certainly is quite interesting. I want to ask whether the source of your phosphate must be bone, or whether other sources may be used?

Mr. Watts: I have not covered this point in these experiments, but I have tried that some time ago. Several years ago I tried to use calcium phosphate furnished by fertilizer companies instead of the bone ash in a series of enamels, but I did not have any success at all. So when I started in on this series, I felt as though I had threshed that ground over to a certain extent, and was not willing to waste time on it. I found in notes from the English society remarks which indicate that only bone ash gives satisfactory results. Yet I also find criticisms of this statement by others, though they do not contradict it.

Mr. Binns: You will find that a man accustomed to use bone ash knows he cannot get the same results from any substitute. It is a perfectly easy matter to determine. Precipitated phosphate will not give the same results as the native bone ash. One theory is that it has something to do with the cellular structure of the bones. Bone is made up of a mass of little cells, and this perhaps has a great bearing on the whole subject, also bone itself is translucent.

In regard to phosphoric acid I have not demonstrated that it leaves the body, but we know that china brought to fusion with Cornwall stone will have a bloated and exaggerated vesicular structure; I have not investigated to see whether these trials show any bloating caused by the escaping of gas.

DRY PRESSED BRICK.

BY

ELLIS LOVEJOY, Columbus, Ohio.

The development stage of dry pressed bricks is long since passed, and we are now working out the minor details to improve the product, and to lower the cost—particularly the latter. It is not my intention to describe the process, but to take up some of the questions which trouble us, and others which mark the limits of the process, and I shall have occasion to depart from my subject and trespass on that of the mud process. The recent convention of sand-lime brick manufacturers reveals that they are going through the troubles of the dry clay process, and it is fortunate for them that their process has not come up sooner, for our experiences have brough about the development of the presses, and made sand-lime bricks possible.

There are three distinct types of dry presses in general use, viz: the hydraulic, the toggle joint, and the roller cam. In the hydraulic the pressure is direct from top and bottom without any movement of the brick in the mould while under pressure.

The pressure in the original toggle joint machine was similar, and the strain was transmitted to the frame of the machine.

The roller cam gave an entirely different pressure. While the pressure was being applied both top and bottom plungers were descending in the mould, but the upper one faster than the lower one. At the bottom of the stroke the motion was reversed and the bottom plungers traveled faster than the top, until the final pressure, when the top plunger was quickly raised, and the brick lifted to the top of the mould box and taken off. The roller cam is not limited to just this motion, but such was the motion of the first machines introduced into this country, and its successful operation brought out American machines follow-

ing substantially the same lines. The idea was to keep the clay in motion in the mould box while under pressure, and through the friction of the clay against the sides of the mould box, knead the clay into a homogeneous mass. The direct pressure types produced the much discussed granulated or "weak" centers, and the range of material they would work successfully was limited, while on the roller cam, it was possible to work any kind of material. Sand lime bricks would have been a difficult problem on the earlier direct pressure types, but on the roller cam, we worked successfully, not only crushed sandstone, but what was more difficult, flint clay with a large percentage of calcine.

In the improved toggle machines, the plungers with the toggles, are attached to massive steel side bars, which receive the strain of the pressure. While the pressure is being applied, the whole pressing mechanism is lowered and raised—the mould boxes remaining stationary—and thus the clay is given the kneading motion which wipes out the granulated centers. The hydraulic has not yet overcome the difficulty. It is not my intention to enter into a discussion of the merits and demerits of the several machines on the market. A detailed description of them would be out of place and superfluous, but I wish to record my disapproval of a statement made to me by a prominent machine man—not intended for publication—namely, that the clay business would not warrant the production of first class machinery. Foundry machines may sell for a few years, but eventually they are driven from the market by the product from the machine shop. I believe that several good ideas in dry press machines have gone down through inferior construction.

On any machine in which the plungers approach each other and squeeze the clay toward the center of the mould, the brick will show a comparative granulation on this center plane, due to a lack of density, quite noticeable even at some distance.

If the pressure is all from the top, the granulation will

be at the bottom, and its position will depend upon the relative degree of motion of the two plungers.

This granulation was attributed to the included air, and all machine manufacturers provide for its escape, either through air holes in the plunger plates, or by releasing the pressure before the final pressure is applied. Naturally any included air under pressure will tend to counteract the compression of the clay, and its effect will be greater at the center of the brick where it has the least chance of escaping, but admitting the effect of the included air and the desirability of allowing it to escape, yet it is not sufficient to account for the granulated surfaces which we get in practice.

Dry or semi-dry clay will not flow under pressure. If a tube punctured with holes from top to bottom to allow the escape of the included air be filled with dry clay, and pressure be applied at the top, we will get a column of clay decreasing in density from top to bottom, due to the friction against the walls of the tube and the immobility of the clay.

A hand press which I used for a number of years applied the pressure just as I have illustrated in the tube. One plate was fixed, and all the pressure was from the other plate. There were no air holes in the sides of the mould, but the air had ample opportunity to escape around the edges of the fixed plate.

All bricks made in that press decreased in density from the side next to the moving plate to the side against the fixed plate, that is, from top to bottom.

In making moulded bricks—a cove for instance—it is necessary to put a loose form in the mould box before putting in the clay.

This form rests on the bottom plunger plate and moves with it, and to the height of the form shuts off the clay from the friction of the sides of the mould box. If the form is one and one-half inches high, then there is about one inch above it, forming the capital of the mould-

ing, which comes in contact with the sides of the mould box. If we fill the mould box with five inches of loose clay which must be compressed to two and one-half inches in the body of the brick, there is three and one-half inches of loose clay over the form, which must be compressed to one inch, unless the clay will flow into the body of the brick and around and to the bottom of the loose form. Some of it is forced out and packed around the form, but so poorly does it accommodate itself to pressure, that the result is a densely packed face,—oftentimes to the bursting point,—on the capital of the moulding above the loose form, and from there to the bottom a relative loosely packed face decreasing in density to the bottom. The opposite face, or back of the brick will have the uniform density from top to bottom that the whole brick would have had if the loose form had been left out.

Figure 1 shows a section of the mould box with loose form.

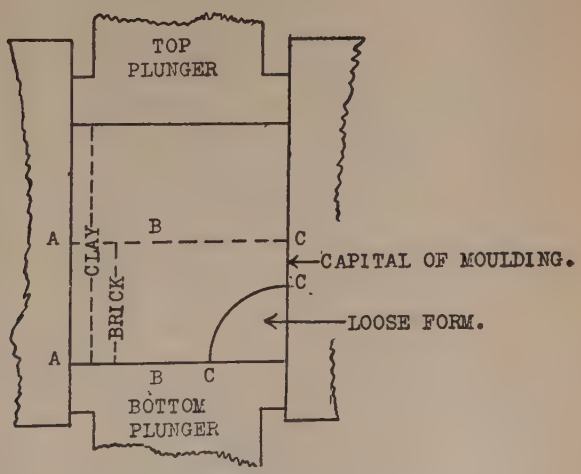


Fig. 1. Diagram showing pressure conditions in brick mold.

Figure 2 illustrates the densities by co-ordinates, the ordinate being the density, the abscissa being the vertical height of the brick, and the curves A, B, and C, show the densities along the sections AA, BB and CC. This is merely an illustration to explain the text, and not a showing of facts.

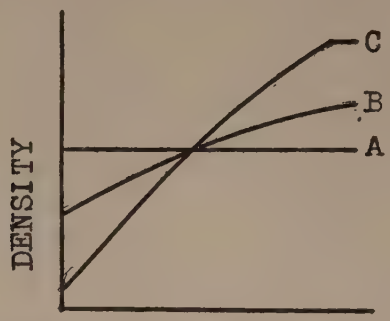


Fig. 2. Diagram showing density relations in brick mold.

In the roller cam motion the clay is most compressed at the top and least at the bottom during the downward stroke, with the reverse during the upward stroke. The loosely packed clay in the bottom offers little resistance to being forced downward in the mould, while the densely packed top offers great resistance to being forced upward during the upward stroke, to the advantage of the bottom of the brick in density. From a scientific standpoint it would be absurd to assert that the total pressure received by the top of the brick is equal to that received by the bottom, and that each is equal to that at the center of the brick.

In practice, however, we notice no difference, and the brick to all intents and purposes is uniform in density from top to bottom.

The later toggle machines recognize the probability of this difference in the top and bottom, and provide for it by an arrangement which in a measure reverses the motion at any point in the stroke. The claim has been made that the motion of the brick under pressure in the mould does not remove the granulated centers but simply glosses them

over, and this claim is reasonable since the centers are only removed through friction against the sides of the mould. In practice we do not recognize any difference in density throughout the brick, but from a theoretical standpoint we cannot believe that the effect of the friction against the sides of the mould will extend to the center of the brick with a material so irresponsive to pressure as dry clay. We believe that the internal core of the brick will have less density than the faces.

If this be true, then the faces being uniform in density, the central core lower, the top and bottom sides above and below the central core must have greater density than the faces.

If these differences exist they are too slight to be noticeable in practice, but they may account for some of our troubles in drying and burning such a body as dry clay, in which the bonding element is not developed as in the wet process.

It was my privilege to be early in the fight for dry press brick. Our factory was the first in Ohio, and so far as I know, the first successful factory east of the Mississippi.

Our first difficult problem was that much discussed one of efflorescence, which appears on the face of the bricks after they are laid in the wall,—a trouble not limited to the dry pressed products, but to which they were particularly susceptible because of the impossibility of making them impervious.

An analysis soon proved it to be a sulphate of the alkalies, lime, etc. The discussions of the time in regard to it would make interesting reading to those of us who went through it without Seger, and without any literature except Prof. Cook's report on the clays of New Jersey.

The alkalies and impurities in the clays gave us at once half of the answer to the problem, but how to account for the sulphur was another matter. Some said it came from the mortar, and this served its turn, but did not convince those of us who found it coming out on the face of the bricks in the piles on the yard.

We tried to make people believe that it came from the atmosphere in our smoky cities, but the trouble was not confined to cities.

I reported to our company that it must come from the sulphur in the coal used in burning, but could not reconcile the fact that the clay on our property with the least alkali showed the most efflorescence. We abandoned its use on this account.

To our chemical work must we lay the blame for not sooner discovering the source of our trouble. "Loss by ignition" covered far more than the innocuous combined water which we were reporting. Prof. Orton has shown us the effects of the carbon which appears in our analyses as combined water, and also mentions the sulphur which finds no place in our reports.

It was called to my attention accidentally. One of our miners brought me a bunch of roots taken from the clay in which the carbon had been replaced by sulphide of iron. This led to an examination of the clays, and I could find none free from sulphur. It became like a puzzle of which you see the end.

Many peculiar and contradictory things were explained. Cause and effect, of which we had begun to doubt the truth when applied to clay, fitted into each other, and our confidence in its truth was re-established. We knew why unweathered clay would not efflorescence in the wall, and why the same clay weathered would effloresce.

We knew why crop clay was dangerous to use. We knew why a clay with less alkali might be worse than one with more.

The solution of the problem with us was simple. We abandoned the traditional weathering of our clay and used only unweathered clay from our mine, hurried it through the mill, into the kiln, roasted out the sulphur, giving nature no change to convert the sulphide into the sulphate, burnt the product hard enough to absorb the alkalies and lime, and sent the bricks to the market with a guarantee that they would not effloresce, and incidentally wiped out the loss account. This was in 1887, and in

a paper before the Ohio Institute of Mining Engineers, these facts were published.

It was not until Seger's work appeared in America that we fully understood the color phenomena of efflorescence.

Hard burning is necessary to prevent the formation of the effloresence. Not only must all the sulphur be roasted out, but also all the alkali and lime must pass into combination and such a degree of combination as to be practically indestructible. There are numerous instances of bricks being in the wall for years before showing any effloresence, and it seems to me that the explanation is in the disintegration of some of the low temperature silicates and the absorption of sulphur from the almosphere.

In the weathered clays, the chemical changes of oxidation result in the formation of sulphates of the alkalies, lime and magnesia. Sulphate of lime does not decompose at temperatures attained in our brick kilns, or at least not to any great degree, and it passes into the brick comparatively unchanged. Sulphates of the alkalies are not decomposed by heat, and under no circumstances in practice can we believe that they are completely volatilized, nor that they are decomposed by silicic acid and form silicates.

Even if such silicates were possible, their permanency is doubtful.

Disintegration will take place, followed by the formation of alkaline carbonates from the carbon di-oxide in the atmosphere, and the reaction between the lime sulphate and these carbonates results in the formation of the alkaline sulphates of which the wall effloresences essentially consist.

In short, the sulphates in the clay continue through the kiln, and the leaching action of rain and sunshine bring them to the surface.

Barium, so successful in the wet process, is not equally applicable to the dry process. Solution must precede chemical reaction. I have frequently found crystals of calcium sulphate like coarse salt scattered through the

clay. Calcium sulphate requires about 400 parts of water for solution, and such crystals will not go into solution in the dry or even semi-dry process. Assuming that they are in solution, not enough barium carbonate, which requires 14000 parts of water, will go into solution to make the precipitation complete. The undissolved barium carbonate is converted into the oxide in the kiln and passes into silicate combination, and its usefulness is at an end.

Seger has pointed out the danger in using barium chloride instead of the carbonate, but the danger is far less in the dry than in the wet process. Dry pressed bricks are dried in the kiln, and as the faces are protected and the ends largely go through close setting, any effloresent salts must come to the surface through the sides where they will do little or no harm.

The small percentage of calcium chloride formed, if it has any appreciable effect, would be an advantage because dry pressed bricks must be very slowly dried. I believe that if the difficulty is overcome by the use of barium it must be through the use of it in the form of chloride.

The stiff mud process need fear no effloresence in the wall if the bricks are burned to the non-absorbent stage. Where the moisture cannot get in the effloresence cannot get out.

The stiff mud meets its trouble in the drier and to a greater degree than in the dry press, and some manufacturers who have changed from dry press to stiff mud, have found themselves in the fire instead of the frying pan. The addition of water brings the sulphate of lime into solution, and in the dry house this comes to the surface. Time is necessary for this solution, and the slower the drying, the longer the water acts on the sulphate, and the greater the amount of sulphate finally brought to the surface.

This, in many instances, is the so-called "kiln white" or "scum," and the use of barium and quick drying is our only solution at the present time. I have found that the best method of introducing the barium is with the water added in the wet pan or pug mill

The water is drawn from a tank holding a definite

supply, to which the weighed quantity of barium is added, and kept in suspension by a stirring device.

There is a "kiln white" or "scum," which comes on the bricks in the kiln, and concerning which we have little information and no solution.

It is not limited to the wet process but is more common to it. The use of wet, dirty, sulphurous coal and wet ware in the kiln tend toward its formation, but so far as the wet ware is concerned, I think we are getting drier white confused with the kiln white.

It occurs in the draft spaces and often spreads out on the sides of the brick like a fan, just as flashing shows where bricks are crossed in the kiln; it therefore follows the flame.

That it is a sulphur compound, we are reasonably certain, but that it comes from the clay, we are not so sure.

It is always worse toward the bottom of the kiln, but this may be only aparent because of the lower temperature not burning it into the bricks and masking it. The best evidence that it is not from the clay is that we have frequently found it on the edges of the draft spaces of the fire brick kiln floor.

In appearance it resembles, when clean, the white coating of antimony on charcoal before the blow pipe, but it is usually a dirty grayish white. It is too insoluble and too infusible to be a deposit of volatilized alkaline sulphate.

Our only remedy is dry, clean coal low in sulphur, and thoroughly dried ware. Much remains to be done on the scum problem, but the first step is a careful distinction between the scumming belonging to the drier even though produced in the kiln, and the scumming produced in the kiln.

To the uninitiated the dry press has one great charm, in that the bricks go direct from the machine to the kiln without drying.

The drier, that center of trouble and discussion in stiff mud bricks, is eliminated. As a matter of fact, the dry

pressed bricks are more difficult to dry than the stiff mud, and require more care.

The reason is obvious. The preparation of the clay for the mud brick, develops the plasticity, and the particles making up the skeleton structure are coated with the plastic material, cementing them together. Moreover, the particles themselves are softened, allowing a more intimate union of the particles and matrix, and a more perfect adjustment under pressure.

When the bricks first come from the machine, they are comparatively soft. They are what they appear to be, a mixture of granular particles with a plastic material. After a while they assume what we call a leather hard condition, without any appreciable drying having taken place, due, I think, to a further development of the colloid properties, or a further softening of the harder particles, either of them absorbing water from that portion already developed or softened. This is the best condition for repressing.

Such is the primary bond of the mud brick, and we hardly realize how strong it is. The drawing together of the particles in drying, even when the bricks are weighed down as they often are when stacked on a car, is but a small part of the strain to which the bond is subjected. The shrinkage strains are far greater.

The outer surface dries first, and shrinks, or tends to do so, while the inner core is still wet and of full size. It would be absurd to assume that the inner core is compressed by the outer casing.

The force necessary to compress clay in such condition would break any of our brick presses, and we hardly accord the primary bond such strength. We cannot believe the clay possesses elastic properties to relieve the strain. We must conclude that the bond is disrupted, and innumerable minute cracks formed, greatly reducing the actual points, or surface, of contact, while the strains are continually being reproduced so long as shrinkage continues. Through it all there is no *visible* rupture of the bond.

In dry clay the bond is *largely mechanical.* The colloid properties are not developed, and if the particles are coated at all it must be with dust and at best imperfectly.

When the pressure is applied, the particles are forced against each other and into each other and held there by interlocking, assisted, of course, by whatever colloid properties may have been developed. The dust fills the interstices under various degrees of pressure according to its amount, and the protection it has received in the inter-locking of the particles, and the opportunity for the escape of the air during the final pressure.

The air, in its escape, may play the further role of sweeping clean the points of contact of the inter-locking particles.

We have found that crop clay, which was highly plastic by the wet process, had a much weaker primary bond that the same clay from under the hill. Finely ground it was worse than coarsely ground.

In working such clays, we frequently found it necessary to introduce ground bats in order to give the skeleton structure.

The sharper the grain of the grog so added, the better the primary bond. The introduction of such material is not to be recommended for a high grade brick. Quite the contrary. Plastic clay finely ground, other things being equal, insures a better *final* bond in the burning, and in every way makes a better brick. We introduced grog to hold the brick together until we could burn the brick, but we limited its use as much as possible.

Bricks held together by such doubtful primary bond must be very carefully dried, in order to preserve the bond for the finishing touch of the fire to make it permanent. Drying in the kiln from five to twelve days is the rule, and in some case two and three weeks are required. It is more a sweating process than a drying one, so slowly is the moisture taken off. Rapid drying would loosen the particles, which would not re-unite in burning, and the result would be a rotten brick.

It is not practical to vitrify dry pressed bricks. This

follows as a corollary of the drying. The primary bond in the green brick becomes the permanent bond in the burned brick.

As we have seen, the primary bond in the mud brick is due to the colloid bodies, and to the finely disintegrated material presumably carrying a higher percentage of fluxes, cementing the larger particles together. The finer state of division alone is sufficient to explain the more ready fusibility of the matrix. The same force which holds the green brick together, continues through the burning, drawing the mass together, until the desired degree of fusion is obtained, and the brick becomes an impervious mass, which is the degree of vitrification I am considering. We might carry the degree of fusion further and the brick will retain its shape until the particles making up the skeleton are dissolved. Not completely, of course, because this stage marks the limit of vitrification, but there is a wide range between the fusion of the matrix to an impervious mass and complete fusion of the whole structure. This range is the safety of the mud process in the production of impervious products.

In the dry process the contact of the particles of the skeleton form the bond. The shrinkage is comparatively little, and is not due in any marked degree to the included fine material.

To vitrify, we must fuse the *particles* of the skeleton mass, which stage marks the limit of practicable vitrification in the mud brick. In the one case the *matrix* fuses and contracts, carrying with it at all stages the larger particles, and imperviousness is attained with its fusion; in the other the fine material may fuse and collect in the bottom of the cells formed by the larger particles, running into and around the points of contact, cementing them together into a permanent bond if we wish to stop at that stage, but only partially filling the cells, and imperviousness can only be effected by the softening of the cell walls themselves and the closing in upon the fused fine material contained therein.

An impervious mud brick may have a stony structure,

while an impervious dry press brick tends toward a glassy structure.

I have seen many samples of beautifully vitrified dry pressed bricks produced by the experimentalist, or promoter, or machinery manufacturer, to show what can be done by the process, but they overlook, or ignore, the fact that in practice the ware in the bottom of the kiln is under pressure, and a brick that keeps its shape on top of the kiln will lose it a few courses lower down, and they also ignore the fact that a column of bricks ten feet high, closely set as they are in the kiln, must carry a long continued higher temperature on top to produce the proper results in the bottom, and to withstand this there must be a wide range between the point at which imperviousness is reached and complete vitrification takes place. The mud brick has this range and the dry press has not.

My explanation of the bonding effect of burning is crude, and I must ask you to consider it rather in the light of an illustration than an explanation of facts.

From the foregoing we naturally find the limits of the dry press process. It is only suited to the manufacture of building bricks, but in this it excells. Its only defect is its lack of imperviousness, and perhaps the difficulty of overcoming effloresence in the wall. In the production of ornamental bricks, it is limited by the immobility of dry clay under pressure. The designs are generally flat. The high reliefs and deep indentations possible in plastic clay are not practical in dry press work.

The cost of manufacture by the dry press is slightly higher than by the plastic clay, due to the longer time and greater amount of fuel required in burning more than anything else. In either case the cost follows the value; we cannot make a fifteen dollar brick by a five dollar treatment, as many prospectuses would make us believe. The dry press has been exploited as a process for fire brick without success. Some No. 2 fire brick are being made, but they are not representative fire bricks. Because of the weak primary bond, the backs of the bricks are frequently cracked and torn from the strains in the kiln where the

bricks are crossed in setting, and the necessity of carrying the temperature to the softening point of the skeleton structure to insure perfect bond, causes deep kiln marks, both of which are undesirable in fire bricks but of no consequence in building bricks. We have made fire bricks on the dry press as far back as 1886 out of No. 2 fire clay, crushed sandstone, and flint fire clay. The latter lacked nothing in refractory qualities, but the bricks lacked the fine grained skin coating which protects the mud fire brick, and enables it to stand the wear and tear in shipping and handling and at the same time is more pleasing to the eye, both of which are important factors in selling. The sand-lime people are now doing what we did with our crushed standstone, except that we were working for a fire brick and used no lime. Such products were possible on the roller cam machines, but I doubt if the earlier styles of toggle joint machines would have worked them successfully. Our only difficulty was with the excessive wear of the moulds and dies, which made bad edges. With badly worn dies there would be no pressure around the edges and at the corners, and without pressure there was no primary bond, and the edges and corners would crumble off in handling either before or after burning.

DISCUSSION.

Mr. Burt: I would like to ask Mr. Lovejoy a question. It has always been a thing hard for me to understand why the roofing tile manufacturers have not yet decided whether the vitrified or open porous roofing tile is the most permanent. As to the question of imperviousness of the bricks, I want to know whether he merely means that the brick is vitrified, or whether it is a question of weather-resisting power. As far as I know, bricks made in ages past, as porous as they could be, have stood for ages. Today, they are urging vitrification, as if this was necessary to withstand the weather.

Mr. Lovejoy: That brings out a great oversight in my paper. I never made any common brick, and this paper relates to face brick. The question of imperviousness

has been the subject of much discussion between the mud and the dry press brick manufacturers. By imperviousness we mean brick that will not absorb any water. The dry pressed brick will absorb any water that touches its face; and ultimately you will find any building made of dry pressed brick which has stood many years, streaked with dirt, and it is absolutely impossible to get it off. The mud bricks, burned to the non-absorption stage, will get as dirty as the dry pressed brick, and even more so. In fact, an enameled brick in the city will get dirty quicker than the dry pressed brick. But one great argument, and a very forceful one, used by the impervious brick manufacturers is that "our brick can be cleaned and the dry pressed brick cannot." There is no question in either case as to weather-resisting properties. If burned sufficiently hard, as it should be, either will resist the weather. At first, the dry pressed brick manufacturers had to fight that question, whether it would stand or not. I know of dry pressed brick laid in a street pavement, eighteen years ago, and it is still there; but yet it is not desirable for paving.

Mr. Wheeler: When you say "impervious," do you know the percentage of absorption?

Mr. Lovejoy: The impervious brick put upon the market now does not absorb anything. I visited one yard in Pennsylvania that makes impervious brick, last spring, and there was a pile of brick on the yard that I thought looked like pretty good brick. I picked up a couple and knocked them together, and I said, "Why, these are pretty good brick; what is the matter?" He said, "They are soft." I said, "I do not believe they would absorb over three percent of water." He answered, "I do not think they will absorb that, but the building brick and paving brick we put out won't absorb anything."

Mr. Blair: I want to make a suggestion in the way of encouraging further investigation along this line. The writer of this paper throws out a suggestion, clothed with doubt, as to what the discoloring matter was, whether sulphur entered largely into it or not, or whether or not it was the sulphates. I want to state a little experience that

I have had along my own line. We make of course, or undertake to make, impervious stiff mud brick. We were troubled by this white coating, so far as the use of the brick for building is concerned. I once approached a gentleman who stands high in our own state as a chemist, and he said he would be able to tell me in a day or two what the trouble was. The only experiment I ever made in regard to this question was to scrape off the entire surface from a dry brick, just from the drier. No matter what kind of coal was used in burning, I never found any discoloration on the outside of such a brick. This would seem to show definitely that it is an accumulation taking place in the drying and not in the burning. I related the same story and submitted the same questions to Professor Noyes, but he was utterly unable to determine just what that is and just how it occurs. I am informed that some scientific board in France has set aside a hundred thousand francs for the determination of this question.

President Gates: I think this is brought out in the paper and attention is called to three distinct classes. Your case is evidently in the second class. When you come to read this paper you will find it very clearly defined. Mr. Lovejoy expressed doubt only in regard to one very different kind of efflorescence.

Mr. Yates: I will ask Mr. Lovejoy whether he ever saw this efflorescence or scum upon the outside of a thoroughly vitrified brick?

Mr. Lovejoy: Well, I most assuredly have. It comes out in the dryer, and when you put the brick in the kiln to vitrify it, it fixes upon the brick. If you introduce some reducing action, when burning the brick, you get a color which masks or obliterates the scum, if you are making buff or cherry red. There is no masking that dryer white in paving brick. It is there and it is going to stay there.

Mr. Parmelee: Mr. President, the French Journal on Ceramics recently mentioned rather a curious method of getting rid of efflorescence on brick, which was said to be patented. The brick is treated with a spray which forms a coating. The paper does not say what it is. The

bricks carry that coating into the kiln. During the process of drying and firing the salts come out of the brick, the coating falls off in firing and carries the efflorescent salts with it.

Mr. Stover: I have a house which I built eight years ago of vitrified brick made in Ohio, paving brick. I had the brick rock-faced and I have been congratulating myself on having it rock-faced, as I got rid of the scumming. Up towards the roof, at the top, there is some scumming. It may be they are not perfectly vitrified brick, as I never tested them.

President Gates: Many bricks supposed to be vitrified are not, to which, I think, Mr. Lovejoy called attention.

Mr. Stover: Scraping off the surface in that case would not seem to cover it.

President Gates: That is the first class he called attention to.

Mr. Lovejoy: That is the point I tried to bring out, the different kinds of white scum. Kiln white, which you get in the dryer is sulphate of lime, burned into the brick, and is there to stay. You can remove it by rock-facing. In the case where the scum appears after the brick is laid in the house, there no doubt must be remaining in it some sulphate which is brought to the surface. The dryer white it brought to the surface and burned in. The kiln white is one feature we do not understand. There is a distinction between kiln white and dryer white, causing the greatest confustion. There are very few manufacturers that notice dryer white, though it comes to the surface in drying. They pay no attention to it until it is brought out in the kiln and then they call it kiln white. In my own experience last year I found unquestionable kiln white not only on the end of bricks but on even the fire brick of the kiln floor.

It could not have been due to efflorescence coming out in the dry house. It was kiln white and I am unable to explain its origin, or how to get rid of it. About a year ago I was on a common brick yard in Zanesville. I was

seeking information about a certain coal. I went to the manager to ask whether he used the coal. He said he used it and liked it, that it did not bring out the scum on the brick. I tried to get him to admit that the scum came from the dryer. He said, "No; if we burn the bricks with wood we do not get the scum. If we burn with this No. 7 coal we do not get much; but if we burn with No. 6 coal the bricks are always badly scummed."

THE CLAYS OF THE UPPER OHIO AND BEAVER RIVER REGION.*

BY

RICHARD R. HICE, Fallston, Pa.

The clays of that portion of the Ohio and Beaver Valleys lying within a radius of six to eight miles of the mouth of the Beaver River (properly Big Beaver Creek), belong to two distinct geological periods, the Carboniferous and the Quarternary. The Carboniferous clays are those horizontal strata known as fire clays, and generally underlie coal horizons; they are usually mined by drifting. They are sometimes called "fossil" clays, and are believed to be the fossil soils on which grew the unequaled vegetation of the Coal Age.

The Quarternary clays belong to two distinct times. A small portion of them are alluvial deposits of the present streams, and are of recent origin, the others are partly river, partly lacustrine deposits, and, it is possible, a portion of these, (part of river deposits), are of earlier age than the Quarternary, being of late Tertiary origin.

The Carboniferous Clays.

The strata of the Carboniferous age have been divided into a number of groups or series, each easily distinguished from the under and overlying formations. The troughs of the Upper Ohio and Beaver Rivers are cut from the middle portion of the Carboniferous deposits. From the Ohio and Pennsylvania state line to the mouth of the Beaver, and up that stream for some miles, the present waters flow near the horizon of a great sandstone, or rather series of sandstones, known as the Pottsville conglomerate (XII). At the state line it is the top member of this sandstone that is

*What is said regarding this region is in the main applicable to the "Panhandle" of West Virginia, and adjacent portions of Ohio, and to much of Western Pennsylvania.

seen at water level, known as the Homewood Sandstone, so named by Dr. I. C. White in 1876.[1]

This is a very persistent stratum, and extends over a large region. It is the Piedmont, Johnston Run, and Homewood in Pennsylvania.[2] It is the Piedmont and Homewood of Maryland,[3] the Homewood and Tonesta of Ohio and the Homewood ofWest Virginia. It is shaly in Kentucky and has not been named there[4] by the West Virginia drillers, and the "Macksburg 500 foot" sand of Ohio.[5]

These facts indicate the wide extent of this stream, and are given to show that conditions producing uniformity in deposition existed over vast areas during the time of the growth of the Carboniferous strata.

At some localities coals are found underlying the Homewood, but within the limits of the Pottsville. They are only found around the margin of the Pottsville area, and need no further mention here than to say that conditions were not favorable for the formation of either coal or clay in the central portions of the Pottsville. No clays are found in the Pottsville in the area under study.

Overlying the Homewood sandstone is a series of strata, named by early geologists the "Lower Productive Series," about 300 feet in thickness. Embraced in this series are a number of workable coal beds, and, being the lowest coal beds known to the early geologists, the origin of the name is obvious. In accordance with recognized rules of nomenclature this name has been replaced by "Alleghany River Series," from the Alleghany River, where they are well developed.

We are only concerned with the clays, and passing upward from the Homewood Sandstone the first clay we find is the Brookville, underlying the coal of that name. This lies but a few feet above the Homewood, and is not

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[1] Sec. Geol. Sur. Penna. Vol. Q page 67.

[2] J. J. Stevenson, Bul. G. S. A. Vol. 15, pg. 204.

[3] Clark and Martin, Bul. G. S. A. Vol 12, pp. 215-222. Q. C. Martin, Maryland Geological Sur. Report on Garrett Co, 1002, pg. 109.

[4] Stevenson, loc. cit. pg. 205.

[5] Bownocker, Geol. Sur. of Ohio, Fourth Ser. Bulletin No. 1, pp. 28-29.

worked at any place in the area under study. It is not known to be of value, is irregular in thickness, often absent, and filled with impurities when present.

A few feet above the Brookville we come to the Clarion horizon. In this region it has been but little worked. On Brady's Run it is six to eight feet in thickness. It lies so close to the Homewood Sandstone, and thus to stream level, that it is generally covered by the gravel terraces which line the valleys of the streams, and frequently it is below the level of good drainage, so that it has been neglected for the more accessible Kittanning clays. It is much purer than the Lower Kittanning clay, but it requires a much longer time to "weather," and is therefor more difficult to wash when used for pottery purposes, but makes a better article of ware than the higher clays.

Thirty to fifty feet above the Clarion horizon comes the Vanport (Ferriferous) limestone. This is the key rock in much of Western Pennsylvania, it is easily identified, and is persistent over a large area.

About thirty feet above the Vanport limestone comes the Kittanning series, consisting of three coals, each with its underlying clay. These three coals are rarely all found. The Lower Kittanning is the most persistent, being rarely absent, while the middle and upper coals are variable, and one being generally absent, or at least undeveloped, they have been confused and frequently misnamed.

The clay underlying the Lower Kittanning coal is, after the Pittsburg coal, the most valuable mineral deposit in Western Pennsylvania. It is persistent, quite constant in quality, has a good roof, and has been so largely worked in this region as to have been sometimes called the "New Brighton clay," to the exclusion of the other clay horizons.

It was long supposed there were but two Kittanning coals, and whichever of the two uppermost was present was invariably called the Upper Kittanning, or "Darlington." The name "Darlington" comes from the phenomenal development of the cannel coal near the town of that name. In the work of the Second Geol. Sur. of Penna. this deposit was identified as the Upper Kittanning, but

is now believed to belong to the Middle Kittanning horizon. About fifty feet above the cannel coal at Cannelton, (three miles from Darlington), is found a coal which is probably the Upper Kittanning.[1]

The clay underlying the Middle Kittanning has been but little worked. It is not uniform in thickness, and is more variable in quality than the Lower Kittanning. It often contains considerable "flint" clay. The Upper Kittanning coal is not developed to any great extent, and it is generally, when present, but a few inches in thickness, and without any workable under clay.[2]

Where the clay under the Middle Kittanning coal has been worked on Brady's Run, it is partly made up of "flint" clay. This does not seem to be confined to any particular part of the clay vein, but is scattered through the stratum indiscriminately, though in greater amount in the upper one-third of the vein. Flint clay has been found at a number of places in the Middle and Upper Kittanning horizons, but I know of but one place in the area under study where any flint clay is found in the Lower Kittanning horizon. This is on the south side of the Ohio River, opposite Beaver, where it is found in one opening.

Above the Kittanning series we find the Freeport series, consisting of two coals and their underlying clays. In the region under study neither of these clays has been worked to any great extent. The Lower Freeport clay is generally quite thin, but at places reaches a workable thickness, and at one point on Brady's Run twenty-two feet have been mined. It has been used for low grade fire brick, but usually carries too much impurities to allow of its use for refractory purposes. It is generally thoroughly burned at cone 6 and 7. The Upper Freeport clay is even less developed than the Lower Freeport.

Each of the Freeport clays is underlaid by a limestone, generally quite thin. These are non-fossiliferous

[1]Mansfield, "Fire Clays, Coals, Titles" pg. 10, published 1905, for private distribution.

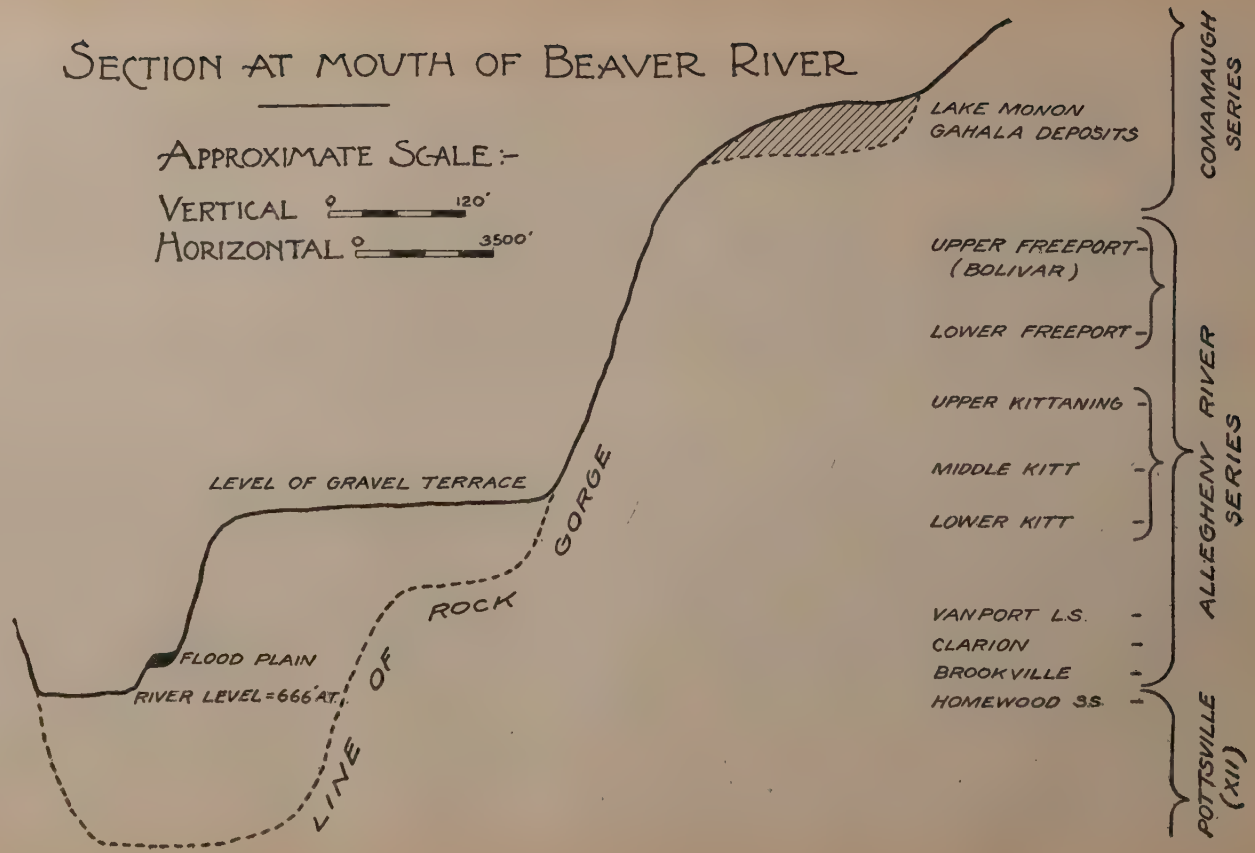
[2]Mansfield, loc. cit. pg. 10, reports seven feet of clay at this horizon. It seems however, to be filled with concreiions of impure iron carbonate.

and are probably fresh water formations. These limestones serve to distinguish the Freeport horizons from the underlying Kittanning series.

The Upper Freeport limestone is sometimes entirely absent, and when this is the case it is often replaced by a deposit of "flint" clay, and is the well known Bolivar horizon. At one point on Brady's Run it is some thirty feet in thickness, but is not now worked in Beaver County. This clay being so close to the Upper Freeport horizon has led to confusion, and the Bolivar and Upper Freeport have not been properly distinguished.*

Above the Freeport series of coals, we find a portion of the Conamaugh series (formerly called the Lower Barren series), so called from the river of that name. This series reaches from the Alleghany River series to the Pittsburg Coal bed (No. 8), and is generally devoid of workable clays.** It is largely composed of shales, many of which are workable, and will produce strong, but rough and poorly colored brick. One thin stratum near the middle of the Conemaugh series is present over a large region, and is the key rock in many places. It is the Crinoidal limestone of the Second Geol. Sur. of Penna. or the old "Green" limestone, now known as the Ames limestone, and found, not only in Pennsylvania, but also in Ohio and West Virginia. It is to be noted, as it marks the last *marine* deposits of the Carboniferous, where it is found.

The great extent of the strata of the Carboniferous series is evidence of uniform conditions existing at the time of deposition. What the conditions then existing were, we can only infer from a study of the deposits themselves, and of the adjacent formation of earlier age. At the time of the deposition of the Carboniferous strata the Alleghany Mountains had not been raised. This we know from the fact that they are largely composed of Carboniferous strata which were laid down in horizontal layers. The carboniferous measures, of which the portion under study is a part, extend in a wide belt from the New York State line southwesterly to Alabama, and perhaps to Arkansas. When formed they were cut off from the waters of


SECTION AT MOUTH OF BEAVER RIVER
APPROXIMATE SCALE:-
VERTICAL 0 120'
HORIZONTAL 0 3500'
LEVEL OF GRAVEL TERRACE
FLOOD PLAIN
RIVER LEVEL = 666' AT
LINE OF ROCK GORGE
LAKE MONON
GAHALA DEPOSITS
UPPER FREEPORT (BOLIVAR)
LOWER FREEPORT
UPPER KITTANING
MIDDLE KITT
LOWER KITT
VANPORT L.S.
CLARION
BROOKVILLE
HOMEWOOD S.S.
CONAMAUGH SERIES
ALLEGHENY RIVER SERIES
POTTSVILLE (XII)

the Atlantic by older formations extending in a narrow belt, in a northeast and southwest direction; on the west they were cut off from what is now the Mississippi valley by the older rocks of the Cincinnati anticlinal; on the north the older formations of New York bounded them, but to the southwest the basin in which these vast deposits were laid down was open to the sea.

There is no evidence in any of the strata that deep water conditions existed at any time in the Pennsylvania-Ohio region. The vast sandstones were formed in shallow water, perhaps not exceeding one hundred feet in depth. The present New Jersey shore is an example of the method of deposition of sandstones, which were only formed on the shores of open bodies of water, and in the structure of sandstones we find all the effects of the forces and energies we now see at work along ocean shores. The variation in size of grain, as the source of material is at hand, or distant; the effects of curves and angles in the coast line on the character of materials deposited and worked and reworked by wave action, under the influence of the driving winds, have been buried and preserved in the hardened and cemented beaches of bygone geological ages. The vast extent of the Homewood, for example, is evidence that the shore line, where the sand accumulated, gradually shifted through an exceedingly slow emergence until the northeast portion of the embayment was raised above water level, the shore line then being in Kentucky or perhaps Tennessee, and the same is true of other sandstone formations.

The Vanport limestone is quite fossiliferous, but there are few, if any, fossils found in it whose living relatives are not shallow water forms, living in water one hundred feet or less in depth. The Freeport limestones are not fossiliferous, and are recognized as fresh or brackish water formations, while the Ames limestone marks the *last* appearance of marine life in this region. It may therefore be said that the evidence of the limestones also points to shallow water conditions existing over large areas.

The coals are evidence in themselves that the surface was above sea level, and they bear internal evidences that

uniformity of conditions attending their deposition extended over large areas. For example, the "partings" found near the middle of the Pittsburg coal bed are found throughout the extent of that formation. In Ohio, Pennsylvania and West Virginia, wherever the stratum is found, these "partings" are in evidence, and may be used for the purpose of identification by one familiar with that rich deposit.

A study of the Carboniferous formation, from the New York state line, southwesterly, shows, however, especially after the Pennsylvania - West Virginia line is crossed, a great thickening of the strata, and the vertical distance between two certain strata where the Ohio River crosses the state line is, therefore, largely increased in central or south-western West Virginia.

The strata themselves are therefore evidence, that during the Carboniferous age the west embayment was constantly oscillating in elevation. In the north-east the amount was very small, gradually increasing to the south-west, towards the open sea. The rate of oscillation was exceedingly slow, but was uniform in direction throughout the extent of the embayment. The rate did not exceed, probably, more than one or two feet in a century. Such a set of conditions is in harmony with the oscillations now in progress in different parts of the world, and account for the relations of the various strata as we now find them.

The Quarternary Clays.

The Quarternary clays belong to two distinct portions of Quarternary time, separated by a vast interval, which includes most of the Glacial period. The Ohio, in common with many other streams, flows in a valley, the sides of which are lined with benches or terraces at various heights, and in the case of the Ohio, of somewhat varying origin.

The life history of the earth is a continuous one of erosion and deposition, but there does not seem to be any reason to supposethat any rocks were ever laid down in the area under study, between the time of the Carboniferous age and the Glacial period, (if we except possible river de-

posits of Tertiary age), indeed there is no evidence to show that much of the upper Ohio basin did not permanently rise above the level of deposition before the close of Carboniferous time. When the land first rose above the level of deposition, erosion began, and has continued since that time.

The first stage of the Ohio river history of which we have knowledge is in pre-glacial times. At that time the present Ohio River basin was divided into a number of independent drainage systems, and a map of the streams at that time would not be recognized as a map of any portion of the Ohio Valley. Then the Upper Alleghany drained northward, through a stream known as the "Carll" river, emptying into the basin now occupied by Lake Erie, but then drained by a stream called the "Erigan" River. The middle portion of the Alleghany basin also emptied into the "Erigan" River, through a stream occupying the valley of the present French Creek. The lower portion of the Alleghany flowed southward to the present site of Pittsburg, where it was joined by the Monongahela River, as at present. Together they flowed northward to the present mouth of the Beaver river, where they were joined by a stream flowing from the highlands of southeastern Ohio, near the site of Wheeling, and the combined stream, then a large river, flowed northward by the valley of the present Beaver, and emptied into the "Erigan" river, westward of the Ohio state line. At that time the relief was very different from the present. The beds of the old streams are much higher than the present ones. Many details of the history of this old river system have been carefully worked out. This stream may be called the "Spencer" river. It came to an abrupt end. The coming of the ice of the Glacial period effectually stopped the line of northern discharge.

The Glacial period is divided into two distinct stages, and one of the earliest in this country is known as the Kansan stage. At that time the ice came within eight or ten miles of the mouth of the Beaver river, effectually blocking the "Spencer" river, and damming back its waters. This resulted in a vast lake, called by Dr. White

Lake Monongahela, which reached its narrow arms far up the Alleghany, up the Monogahela valley far into West Virginia, and down the Ohio valley until the waters overflowed into that portion of the present Ohio basin lying westward of the "Spencer" drainage. This overflow naturally resulted in cutting down the divide between the "Spencer" basin and the stream occupying the Ohio valley beyond the present site of Wheeling.

During the life of Lake Monongahela large lacustrine deposits were laid down, the character depending on the source of materials, and we therefore now have on benches which are the remnants of this old river and lake bed a large variety of materials, clays, sands and gravels, sometimes thoroughly intermingled, but occasionally assorted by the action of the lake or river waters. In the valley of the Monongahela these deposits are formed of local materials, on the Alleghany a mixture of local and glacial materials, and on the Beaver they are mainly derived from glacial materials, for here the ice left large deposits but a few miles away. Where these deposits are clays they constitute the first and earliest of the Quarternary clays.

How long the ice held back the waters of Lake Monongahela we do not know, but either the ice itself, or the debris deposited by it, held them until the present line of discharge was established. The cutting down of the divide, and establishment of the drainage of the Ohio river in the present direction was, however, rapidly accomplished, and this cutting continued until the main streams flowed in valleys much below the present water level.

The streams continued to occupy those now buried channels until the last stage of the Glacial period in this region, the invasion of the ice known as the Wisconsin stage. This occurred long after the Kansan stage, and reached into the upper Ohio valleys to practically the same limits as the Kansan ice. This invasion brought the streams occupying these deeply excavated valleys to an end. The Wisconsin ice carried immense quantities of debris, and the streams flowing southward, although greatly increased by the melting ice, were unable to carry

the great burden thus thrust upon them, and, consequently, the gravels derived from the ice were carried but a short distance and dropped by the water, filling the deep channels of the rivers, at the mouth of the Beaver, to a height of one hundred and twenty feet above the present river level. After the retreat of the ice the streams began at once the re-excavation of their beds, but have not yet succeeded in removing the vast accumulations of glacially derived materials. They now have reached a stage where they are not cutting so rapidly, and consequently we find a second series of Quarternary clays in the flood plains of the present streams. These clays are of but little value. They are generally quite sandy, but occasionally will produce a fine red brick, which is only used locally. Thus the Quaternary clays are of two distinct ages. The last, still in the process of formation, while those found on the remnants of the "Spencer" river bed belong to a time running back to the first of the Glacial period, a period long before the falls of Niagara were formed, for these belong to the last of that period, and not to be measured by thousands but by tens of thousands of years.

DISCUSSION.

Mr. Stover: I would like to ask Mr. Hice at about what cone the Upper and Lower Kittanning clay will vitrify?

Mr. Hice: At about eight.

Mr. Stover: Is that Upper or Lower?

Mr. Hice: Lower, the Upper, taking the run of it, is possibly a little higher, I think.

Mr. Stover: You mean that one lies underneath the other?

Mr. Hice: Thirty or forty feet below.

Mr. Stover: Mined in the same shaft?

Mr. Hice: Right in the drift.

Mr. Yates: I would like to ask the gentleman a few questions. Having described the carboniferous period, starting with the Clarion group, what experience has he

had with the Lower Clarion group that caps the Freeport, what is the thickness of the clay there?

Mr. Hice: Will the gentleman state his question more definitely?

Mr. Yates: I mean the bottom of the so-called Warren. What is the thickness of that?

Mr. Hice: The Clarion?

Mr. Yates: Yes.

Mr. Hice: Possibly five or six feet with us.

Mr. Yates: Going down under the Homewood sandstone, what thickness do you find?

Mr. Hice: There is none with us.

Mr. Yates: We get flint sandstone with us in Pennsylvania. One thing in particular I want to learn. You pay little attention to the Middle Kittanning; have you explored this seam to know whether it is really reliable or not, or have you gone into the deposit to know whether it is thick or thin or what to rely on?

Mr. Hice: We do not have the Middle Kittanning. There are three Kittanning clays and there are very few places where all three are found. With us we have the Upper and Lower developed, but the Middle Kittanning is not always found, and when found is not more than three to six inches thick, and the clay is of no value.

Mr. Yates: Suppose you have only found the coal blossom,—have you explored enough to know what thickness of clay you have below?

Mr. Hice: There is an outcrop on a slope, not a crop in the ordinary sense, not a weathered crop, but where it has been cut down almost vertically and a good exposure as we went in.

Mr. Yates: What is the thickness of the fireclay?

Mr. Hice: Almost nothing.

Mr. Yates: Where the coals are thin, do not you find thick deposits of clay, and vice versa? All through our section where we find thin coal we find thick clay.

Mr. Hice: It may be possible, but I know of no such rule.

CAUSES OF BODY CRAZING IN SEWER PIPE.

BY

WALTER A. HULL, Drummond, Pa.

When the writer became connected with the factory where the observations to be presented in this discussion were made, he found a dearth of kiln burners; the last man who made any pretense to experience or ability in that line had tendered his resignation, and the helpers that remained could not be accused of having any deep seated prejudices. The clay used is a coal measure fire clay, containing, as is common with clays of this class, considerable carbonaceous matter. That oxidation was a prime requisite to successful burning was a foregone conclusion. As many experienced and successful kiln burners fail to realize the importance of this factor, it was considered best not to secure one. In conducting the burning with the help immediately available, the writer made a virtue of necessity and studied the problems first hand, at short range. Among those which presented themselves, the most persistent and what promised for a time to be the most baffling was "crazing;" not glaze crazing, taking place during or after the cooling of a kiln, but body crazing, occurring during the burning, as an examination of the crazed pipe plainly indicates. The glaze always extends down into the cracks and in many cases covers them completely, leaving only a slight undulation on the surface of the pipe to betray their presence.

When we first found it necessary to deal with crazing, it all looked alike to us. All the contributary causes were considered and all the possible preventive measures were taken. The pipe were set dry, and the kilns carried along most cautiously during the water smoking and well into the dehydration period. At the same time great pains were taken to prevent fluctuations of temperature; dampers were lowered during the cleaning of the fires, and light

firing was done at frequent intervals. It also became the practice in cleaning the fires to clean a hole and skip a hole, clinkering the remaining alternate furnaces in turn. The day men would clean every other one and the night men do the balance, thus extending the process over a considerable period of time. By means of all these precautions we did away with the trouble for a time, but it came back. Burners who by this time were considered trustworthy were accused of carelessness, and yet none could be detected. The trouble was finally located in the oxidation period. We had taken it for granted that the greatest danger was passed by the time a kiln was red to the bottom, and yet had exercised what seemed to be reasonable care up to the finish. As was stated at the outset, the clay used requires an extended period of vigorous oxidation. In order to provide for this our practice was to commence to increase the air excess soon after the kiln was cherry red to the bottom, at the same time arresting the progress of the rise of temperature and holding it practically constant. This was done by leaving a considerable open space over the fuel bed to permit the influx of air. Inclined grates without doors are used, and the method described was a simple and effective means of accomplishing the necessary oxidation. It was the intention to maintain a constant temperature with a good air excess for twenty-four hours or more before proceeding to finish the burn. It was observed, however, that the crazing was worst in those burns in which our oxidation treatment was most vigorous. The reason is apparent when we consider the causes of crazing which will be discussed further along, for while no perceptible cooling of kilns took place, the tendency of the method was to produce comparatively short and rapid fluctuations of temperature. The burners had learned at the beginning that with a good draught and a moderate bed of fuel, the temperature of the kiln would rise rapidly at this stage unless the fires were left very much open. Consequently a reasonably large opening would be left over each fire when coaling. This would give an air excess even immediately after firing. The trouble

was that as the fires burned down the openings would grow larger instead of smaller, so that when the furnace was making the most heat and the coal was distilling off volatile fuel most rapidly, the air influx would be least; on the other hand, when the bed of fuel was reduced to a mass of incandescent coke, which would burn perfectly without any secondary air inlet, the mouth of the furnace would be wide open and doing business on a large scale. The natural remedy was to use a lower damper during this stage of the burning than when heating up, and to try to provide for an air excess by keeping a thin bed of fuel on the grates. It is not easy, however, to secure a uniformly thin bed of fuel on inclined bars and at the same time to keep the furnace mouth closed with coal. Another difficulty is that with a coal which cokes and hangs, constant vigilance is required to keep big holes from burning through and making the very trouble which we are striving to overcome. At any rate we succeeded fairly well as to crazing, but the oxidation secured was too feeble and it was found necessary to admit more air. It had not been found satisfactory to regulate this air influx at the furnace mouth by means of the fuel itself, so more uniform openings were provided.

The practice now in operation is as follows: After each fire has recovered from its first cleaning, a five inch sewer pipe is inserted through the fuel bed near the bottom of the bars. The burner pays no further attention to this pipe until he is ready to allow the kiln to proceed towards vitrification. All the pipes are then withdrawn. The result is simply to increase the air excess during the period when it is most essential. As the opening is just as large immediately before coaling as at any other time, the air excess of the kiln is somewhat extravagant after each fresh coaling has ceased to throw off its volatile combustibles, but as the increase is gradual no harm is done and it is not found necessary to damper these secondary air holes. Oxidation is thus accomplished without producing fire cracks. In the meantime, however, it had been observed that there were two distinct kinds of crazing, apparently arising at

different stages of the burning and due to separate causes. The irregular zig zag cracks usually circumferential, which are sometimes observed on pipes of any size when exposed to the direct play of the gases, we will designate as "fire cracks," while those which we occasionally see extending in a net work over the entire surface of big pipe that have been heated too rapidly in the first stages of the burning, and which give them the appearance of alligator skin, we will call for convenience "water cracks." The cause already stated suggests the obvious remedy for this kind of crazing.

In dealing with defects of any sort one is sure to realize that "experience is a hard school" and to make use of all the facts and probable theories available. The following line of reasoning has thus been forced upon the writer by necessity rather than by any passionate love of theory for theory's sake.

For the better understanding of the behavior of sewer pipe in burning, it is necessary to study its structure briefly, and this leads us to a consideration of the manner in which the clay is forced into the form of pipe in the press. Here we have a hollow cylinder with a diameter of say, 24 inches. At the bottom, the walls of this cylinder are suddenly constricted so that they form the outer portion of a comparatively flat basin. In the center of the above cylinder is a rod, held in place by a spider. At a level corresponding closely to that at which the outer cylinder "dishes in," the center rod "dishes out;" that is, it is suddenly enlarged by the "core die," or "bell." Between the outer basin and the inner bell remains an annular space as wide as the thickness of the green pipe to be made in this particular die. We have in the above hollow cylinder, a solid, compact mass of plastic clay, under heavy pressure, traveling downward. At the bottom the whole mass is forced to travel toward the narrow, circular slot, mentioned above. Considering the outside only of this clay column its surface may be regarded as a compressed sheet, polished by contact with the surrounding wall. When this sheet reaches the constricted portion of the die

it is forced to travel over a rapidly narrowing surface, causing it to double and thicken to a compressed layer, which is somewhat denser than the clay body within it. This outer layer is not distinct and separate from the body of the pipe, but the laminations are strong enough to cause an easy separation, along regular lines of cleavage. The body is laminated throughout, but it is chiefly the superficial layer which we have to consider in the study of crazing. To simplify this discussion the pipe will be spoken of as if it consisted of two or more or less distinct portions, the "outer layer" and the "body of the pipe." We may also consider that the cleavage planes caused by lamination form barriers between the body and the "outer layer" of the pipe, blockading the line of travel from one to the other of either heat or gases. This effect is more pronounced than might be supposed. It is easy to believe that cleavage, by breaking the continuity of the substance, will cause heat to pass through it less readily. That the laminated structure also retards the passage of gas can be seen by examining the longitudinal fracture of a burned pipe which has a black center. From the spigot end oxidation has penetrated much deeper than from the sides, although the end has been protected by resting on the pipe beneath it while the sides have been fully exposed. This same tendency is more strikingly demonstrated by placing a broken piece in the kiln with the edges exposed. Unless the piece be very large it will be oxidized throughout though the pipes of the same thickness are black centered.

The laminae of the pipe being thus separated by barriers, the pipe itself is the more easily affected by the causes ordinarily assigned to the cracking of clay bodies, viz:

I. The more rapid expansion of one portion than of another.

II. The more rapid contraction of one portion than of another.

III. The pressure of confined gases generated within the clay body.

In considering the first two causes, it may be assumed

that the changes in size which occur in the *body* of the pipe take place gradually, and are not affected by slight fluctuations of the kiln temperature. Therefore, for purposes of discussion, the outer layer of the pipe may be said to expand or contract independently of the relatively inert body within it, and this expansion or contraction may produce pressure or stress which is greater than the strength of the "outer layer." The natural consequence of such action would be the disruption of the outer layer.

Taking the first possible cause separately it may be said that it seems to be the least probable of the three. The general tendency of the entire process of drying and burning is towards shrinkage, and as the progress of the inner body is always a stage behind that of the outer portion, the latter is kept in a state of tension rather than of compression, and a sudden fluctuation which would relieve the compression would be less likely to do damage than one which would increase it. While a sudden flash of heat might expand the outer layer of the pipe to such an extent that it would crack after the fashion of the crazing of a glaze, yet the crushing strength of the material is undoubtedly much greater than its tensile strength, so that we would expect tension rather than compression to produce the superficial cracking.

The second cause is a more probable one. Assume that the outer layer of a pipe is already in a state of tension, at say, a cherry red heat. Suppose that one fire or more burns low for a short time, and that a strong draught draws air in over the bed of coals. A comparatively cold current may play against one side of the pipe in question and chill it superficially. The added tension would crack the outer portion of the body if the contraction were too great and too sudden. Repeated observations has led to the belief that this action is responsible for most of the long zig zag "fire cracks" with which all sewer pipe makers are more or less familiar. "Fire cracks" of this nature are seldom seen on the bottom pipe of a kiln where fluctuations are least sudden. They are common on pipe of any size set near the tops of the bags. Big pipe set high in the kiln

and not protected from the direct play of the fire gases are sometimes affected. It is here that fluctuations of temperature are most pronounced. Nearer the bottom of the kiln the influence of the hot ware above, together with the more thorough mixing of the fire gases, tends to equalize the conditions. It has been observed repeatedly that the fire cracks are usually found where the currents of gas travel most freely. If the pipes lean a little in some portion of a kiln, leaving an invitingly wide open space for the draught to follow, comparatively small pipe crazed on one side may be found next the open space, whereas larger pipe in the next ring will not be affected. It seems to be a case of superficial shrinkage, due to the cooling of the outer portion of the pipe. The inner protected portion is slow to feel the effect of the cold current, and does not contract with the outer layer.

The third cause—pressure of confined gases generated within the clay body—is responsible for the checker-work cracks previously designated as "water" cracks. This sort of crazing is the result of the same action which causes blowing. All sewer pipe burners know that if they were to heat a kiln of big pipe rapidly from the beginning, the result would be precisely the same as if small gunpowder mines had been placed within the body of the pipe. Great slabs would be broken loose on the outside of the pipe, and in some cases these slabs would be found at the bottom of the kiln, having been actually blown off by the force of an explosion. For this phenomenon there is but one probable explanation—the formation of gas within the pipe more rapidly than it can make its way out through the moderately porous body. The offending gas is unquestionably steam. The shales and fire-clays used for sewer pipe do not contain anything except water which is either volatile or chemically destructive at low temperatures. The comparatively low percentage of bituminous matter could not be considered dangerous, even if it were much more easily volatile than it is. As for the carbonates, sulphates and other destructible compounds, they are known to separate reluctantly and only at temperatures at which the clay

body has attained a high degree of both porosity and strength. It is safe to assume, also, that the chemical water comes off gradually and, by reason of the then porous condition of the body, makes its way to the surface easily and without any disturbance.

The responsibility then rests jointly with the mechanical and the hygroscopic water. The guilt may belong to the mechanical water exclusively, or altogether to the hygroscopic water, but it is also possible for the hygroscopic water to be the red-handed individual, while the mechanical water is equally culpable as an accessory before the fact. As an illustration of the first case, the writer cites an instance in which a fifteen inch pipe was set green in a kiln of dry pipe, which was to be heated up comparatively rapidly. This green pipe was marked for identification, but this precaution proved to be unnecessary, for when the kiln was opened our "test piece" looked like a very ancient chestnut stump from which most of the decayed sap-wood had fallen off in patches, exposing the relatively sound heart. Our marks were found on a detached slab, which lay on the floor of the kiln. It would not be fair to charge this ruin to the account of hygroscopic water. The presumption is that our pet was a hopeless wreck long before the dawn of the hygroscopic morning.

On the other hand, pipe have been left in the dryer for days after they would ordinarily be pronounced dry; the kiln in which these alleged dry pipe were set was then kept on low fire for four days or longer, the temperature not greatly exceeding 100 degrees Fahrenheit, and then carried along at a moderate rate. Thirty inch pipe treated in this way have been known to blow. The writer is not inclined to hold the mechanical water accountable, although he has no direct proof that the last fraction of a per cent of mechanical water had passed off before the blowing occurred. The lack of exact records of these burns is to be regretted, but this is to be explained by the fact that since we have kept fairly accurate temperature records, we have had no cases of blowing to record.

The third case—that of double responsibility,—is just as probable as the other two. Suppose a few big pipe to be set greener than the balance of the kiln, and assume that the burner takes this into consideration and handles the kiln with a little extra caution. For three days or longer the temperature of the kiln remains below the boiling point. The dry pipe have nothing to do but to warm up at about the same rate as the kiln atmosphere. In the meantime the green pipe are drying, and because of the evaporation going on within them, are keeping cool. As the kiln temperature rises, that of the dry pipe keeps pace with it while that of the drying pipe lags farther and farther behind. When it is finally dry mechanically and just ready for congratulation on that score, it suddenly discovers that its neighbors are much hotter than itself and are now serenely passing through the second stage of the drying. At the same time our tardy pipe begins to realize that the kiln atmosphere is hotter than it has seemed till now. A short time ago the refreshing influence of evaporation was sufficient to keep it fairly comfortable. It now becomes alarmed and tries to hurry, but it cannot gain appreciably. Its fellows have taken advantage of their handicap. The unfortunate individual has been sweating comfortably all the while, but now it begins to steam—moderately at first and then in a frenzied sort of way, which plays havoc with its outer garments. Bye and bye, after the race is over, the verdict will be "green pipe—blowed, chuck." Or if it be a less desperate case the drawing gang will observe a crazed pipe here and there, and decide that the country is going to the dogs. But we must not anticipate. Though the poor pipe may be shamefully denuded yet it must stay in that kiln until the finish. After a time it reaches the dehydration stage and forges along lamely, while its companions of a few days since are passing out of that stage into the next, where they will tarry a while for a period of much needed oxidation. This is, indeed, an opportunity for the laggard; it will not waste time by pausing for oxidation, but will rush along and gather up what it can as it goes. In fact, no alternative

remains. The burner is busy outside and a vitrifying atmosphere is coming through the kiln. The pores are closing in the outer layer and oxidation is no longer possible. There is but one thing to do—the pipe rushes along, takes its glaze and finishes with a bright face and a dark heart. Some days later one of the boys breaks this pipe open and remarks, "bluing spoils them; blowed pipe most always have a black center." The boy is correct in his observation but not in his conclusion. Reduction and blowing may follow indirectly from the same original condition, but one does not cause the other unless our reasoning is grossly erroneous.

It is pretty generally conceded that blowing is directly attributable to steam pressure within the body of the pipe. The explanation is a simple one and the effected pipe look the part. With crazing, however, the case is not so obvious. We can readily conceive of steam forming so rapidly that it cannot escape through the pores and must destroy the pipe by its expansive force; from this it is but a single step of the imagination to picture this same steam forming slowly in the pipe body, and gradually making its way from one porous layer to another in its quiet and harmless escape to the surface. Now assume that we have a condition between the two. Steam is passing out through the pores, but not as rapidly as it is being formed, and the pressure is increasing. Something must give way. The weakest portion is the outermost lamina, and this, because of its density it also the most stubborn barrier. Here the expanding steam exerts its accumulated pressure and the crust yields. Instead of a concentrated explosion we have a miniature earthquake. Why the cracks should describe their characteristic alligator skin figures is not easy to account for. In fact, this explanation has been accepted by the writer with hesitation after making observations that ought to be conclusive. To illustrate—the kiln is heated too fast in the first few days of the burn and then allowed to lag. The top pipe are blown and the bottom pipe are perfect, while between the two is a regular gradation of blowing, blowing and crazing combined, crazing

alone, less crazing and no crazing. Again the phenomenon may be reversed. In this case the kiln has been allowed to idle along for two or three days, taking just enough heat to carry the top pipe well along through the drying, while the bottom pipe lag behind in a cooler and moister atmosphere. The burner raises his fires a little, the bottom pipe are not ready for the change and suffer in consequence. Here the gradation is reversed; perfect pipe on top, then crazed pipe with blown pipe below, if the case be a violent one. Such occurrences seem to show an established relation between blowing and the defects which we have termed "water-cracks."

The conditions which result in crazing are so various and elusive that the foregoing discussions have been resorted to in order to demonstrate that there are two distinct kinds of crazing:

1. The fire crack type, which is caused by sudden fluctuations in temperature. No limits have been assigned to the time or period at which these fluctuations are destructive, but it has been shown that their action is effective in the oxidation period.

2. The alligator variety resulting directly from the pressure of confined steam generated too rapidly, because of a poorly arranged program in the early stages of the burning.

It may be said in conclusion that vitrification plays an active part in bringing these defects into prominence. Crazing would hardly be detected on an under-burned pipe, but the tendency of vitrification is toward shrinkage, and the final appearance of the crazed pipe is like that of the little flannels on the child whose mother didn't use proper soap—they gap and curl at the seams.

REPORT OF COMMITTEE ON CERAMIC LITERATURE.

Charles F. Binns, Chairman.

THE POTTERY GAZETTE, LONDON, 1904.

REPORTED BY CHARLES F. BINNS.

February

Porcelain pipes for water. An American Consular report states that these are made in Saxony. The advantages are obvious. The pipes are encased in iron, the cost is about $750.00 per mile.

The clay deposits of Devon and Cornwall: A continuation and conclusion of articles which appeared in October, November and December, 1903. Written by William Jackson, of real interest and value to those concerned with clay production.

April

The effect of bone in ceramic mixtures. Bone has its highest fusing effect at 17 per cent. The physical structure of the bone has no effect. The infusible character of bone china depends upon an excess of bone.

English hand-made glass. A descriptive article well illustrated by photographs.

May

Fuel and its application. The first of a series of articles on this subject by William Jackson. Well worth reading.

June

Fuel, continued.

July

Fuel, continued.

August

Fuel, continued.

German technical instruction in pottery. A description of the courses and subjects taught in Germany.

Metallic lusters on Ceramics and Glass. German methods.

The preparation and behavior of insoluble fritts. Wilton P. Rix.

September

German technical instruction in pottery.

Insoluble fritts, continued. A paper read before the Society of Arts and concerned with the lead poisoning question. The term "insoluble" refers to insolubility in the gastric juice and similar acids.

REPORTED BY H. E. ASHLEY.

THE IRON AGE.

May 18th, 1905, p. 1604.

The Decalomania Industry in America.

A trade writeup of the Meyercord Company's works in Chicago. 500 words.

ENGINEERING NEWS.

No. 22, p. 561.

Some Recent Tests of Concrete in Tension and Compression at the Columbia University Laboratories, by Ira H. Woolson. 4000 words, 4 illustrations, 18 diagrams.

OHIO GEOLOGICAL SURVEY.

Fourth Series, Bulletin No. 3, 1904.

The Manufacture of Hydraulic Cements, by Albert Victor Bleininger, 391 pages, illustrated.

TONINDUSTRIE ZEITUNG, FOR 1904.

REPORTED BY ALBERT VICTOR BLEININGER.

One of the most important essays which appeared in the past year is the reproduction of a lecture by Ludwig before the German Society of Refractory Clay Ware Manufacturers, in which he calls attention to the importance of the work of Richter, viewed in the light of modern chemical researches.

The fusion of silicates results in the production of igneous solutions holding dissolved various silicates. Thus Seger cone No. 1 consisting of a mixture of feldspar, kaolin, quartz and ferric oxide, when fused is a mutual solution of feldspar, quartz, augite or hornblende. If we could cool this mass slowly these silicates would crystalize out one after the other. This has actually been done by Prof. Vogt, of Christiania. This investigator has shown that the melting point of fusion is always highest when only one definite silicate crystalizes out and lowest when it represents a mixture of several silicates. This coincides perfectly with the general phenomenon observed in all solutions, namely, that on dissolving any substance a decrease of the melting point takes place. It is immaterial whether the melting point lies at 0° or at 1200 degrees Centigrade The compositions of the slags and glazes are practical illustrations inasmuch as the most fusible combinations of either kind of silicate are always the most complex ones. When two silicates are combined they invariably result in a mixture having a lower melting point than either, owing to the formation of the so-called eutectic mixture. Thus, mono calcium silicate fuses at cone 15, on adding one molecule of

silica to two molecules of this silicate, the melting point falls to cone 7, but on adding more quartz the fusion point again rises. Again, in a clay containing beside silica and alumina the various fluxes, the melting point is governed by the fusing point of the eutectic mixture of these constituents, which represents the most fusible combination possible. This explains also why feldspar begins its fusing effect in a body much below its melting point. The eutectic mixture is invariably high in fluxes at the lower temperatures, but takes up more and more silica as the temperature is raised. Silicates proper are more fusible than high alumina mixtures, and hence more silica is brought into solution than alumina, which is dissolved only at high temperatures. This explains the fact that aluminous clays show the greatest refractoriness. As the solution increases in amount the clay softens, and finally when there remains but little undissolved matter fusion takes place. This manner of melting is characteristic of solutions, while substances, homogenously crystalline, melt suddenly without softening. Thus the final melting point depends upon the ratio of the alumina to the silica and the amount and kind of flux.

The foundation of these fusion phenomena is the following general law applying to dilute solutions:

Equi-molecular quantities of different substances dissolved in equal amounts of the same solvent lower the melting point in the same degree.

This is one of the most important laws of physical chemistry, and it is an interesting fact that it was discovered by a ceramic investigator, Richter, in 1868, while van't Hoff proved the general truth of the law by mathematical reasoning in 1886.

The law applies to substances in general indifferent as to whether they are bases or acids, the only requirement being that they are soluble. With reference to clay we must therefore consider lime magnesia, potash, soda and titanic acid as the dissolved substances.

If now we are to compare refractory clays as to their melting points, we must calculate the molecular formula of each clay making the alumina equivalent equal to unity, and adding the equivalents of various fluxes, obtaining thus a formula like

$$Al_2O_3+2.125\ SiO_2+0.0755\ RO.$$

Since in this expression there are but two variables, Ludwig plotted the silica equivalent as the abscissa of a curve and ten times the equivalent of the RO as the ordinate, and in this manner he located various German fireclays in a chart, verifying the clays by their melting points in Seger cones.

Richter's law, strictly speaking, applies only to dilute solutions, and hence if the amount of fluxes is considerable the law loses much of its force. It does not apply, therefore, completely to glazes or glasses. Differences from this general law are not due to chemical reasons since it does not matter in what chemical combination a flux

enters into a clay, whether as feldspar or as potash, but must be sought for in the different mechanical conditions.

Ludwig summarizes his work in the following conclusions:

1st. Richter's law is a special case of the general law of dilute solutions.

2nd. This law is restricted by the following conditions:

a. It applies only to very dilute solutions, that is, clays with a small amount of fluxes and not to brick clays or glazes.

b. It assumes intimate mixture.

c. Iron shows a different effect, due to its two stages of oxidation since one molecule of ferric oxide corresponds to two molecules of ferrous oxide. A given percentage of iron contains fewer molecules of ferric oxide than of ferrous oxide, since the former has a higher molecular weight. On changing to the ferrous oxide the number of molecules is doubled, and hence the fluxing effect is doubled.

3rd. The analysis of a fireclay is of great importance in estimating the refractoriness.

4th. The estimation of the refractoriness by means of the percentages of alumina and fluxes leads to erroneous results.

Free Lime in Portland Cement.

Nos. 140 and 152.

Baikoff advocates the use of phenol pthalein in determining the amount of free calcium oxide in cement, and it is his opinion that this reaction is of value in examining cements which are either mixed with natural cement or which seem to show inconstancy in volume, furnishing quantitative as well as qualitative data.

Volatilization of Alkali Sulphates.

No. 148.

In a refractory clay ware establishment it was observed that the surface of some of the ware was vigorously attacked so that it had a blistery, foamy rough appearance. On investigation of the cause of this phenomenon by the laboratory of Seger and Cramer, it was found that this deposition took place on the sides exposed to the fire gases, and evidently was caused by the volatilization of sodium sulphate. It was then found that some grog had been used which had been part of some chemical ware. Analysis showed the presence of considerable sodium sulphate in the grog, and thus explained the cause of the trouble.

Changes Suffered by Zinc Muffles.

Dr. Steger found by chemical examination that zinc muffles were attacked considerably by energetic chemical reactions, owing to the formation of zinc spinel ($ZnO\ Al_2O_3$) Willemite, $2\ ZnO\ SiO_2$, and tridymite. This chemical action of zinc vapor extends deep into the

walls of the muffle. Dr. Muehlhauser has found that the formation of zinc spinel takes place principally when the muffle is still new and hence porous, having formed as yet no glaze on the side turned towards the fire gases, allowing the fuel gases as well as the zinc vapors to diffuse through. The attack of the clay substance takes place according to the reaction:

$$Al_2O_3\ 2\ SiO_2 + Zn + CO_2 = Al_2O_3\ ZnO + CO + 2\ SiO_2$$

The reduction temperature of zinc oxide is 1000 degrees centigrade, and it may be assumed that zinc spinel forms at temperatures above 1000°C.

The fluid slag is also absorbed by the muffle and exerts a powerful influence on the muffle body structure, especially towards the finish of a charge when the temperature is high. The heat increases in the muffle from 780 to 1188°C, in the furnace from 1100 to 1300°C. Any defects or structure laminations are at once followed up by the slag. Since the absorption of zinc by the muffle is considerable in amount during the first stage of its use, it is of great economic importance that this absorption of vapor be reduced as much as possible by the proper proportioning of the body constituents.

Clay Efflorescence.

No. 43.

In this number is published the report made by Dr. Maeckler on the efflorescence shown by various kinds of bricks, burned hard and soft. In this work not only the amount of the soluble salts, calcium sulphate, magnesium sulphate, and the sulphates of the alkalies is determined, but also the porosity and the tendency to show efflorescence after saturating the brick with distilled water. The total amounts of the sum of the calcium, magnesium and alkali sulphates varied from 0.7668 per cent. down to 0.0134 per cent. in fifty samples. It was found in this work that chemical analysis does not show definitely whether or not a brick will effloresce. This work is to be continued, at the expense of the German Society of Clay, Cement and Lime Manufacturers.

Hydration of Gypsum.

No. 77.

The fact that the rapidity of setting of gypsum may be accelerated or retarded by the use of different aqueous salt solutions is discussed by Dr. Paul Rohland. This reaction was formerly ascribed by the same investigator to catalysis, but is now explained by him on the ground of the general laws of solution. The principal law governing such hydration reactions is that all substances which accelerate the hydration of the calcium sulphate increase its solution tension whole, those that decrease the tension also retard the rate of hydration. This law is reinforced by other laws working in the same direction.

One of these is, that all substances which remove one of the ions from solutions increase the solubility, while those which have an ion common with the solid lower the solubility. Exceptions to these laws have been satisfactorily explained by the formation of complex ions. These laws have as a consequence the conclusion that the velocity of hydration must be the greater, the greater the solution tension of the hydrating body is as compared with that of water, and also that the substance which is hydrating must first go in solution before the union with the water takes place.

Work on Lime-Sand Brick.

No. 44.

Prof. M. Glasenapp has shown in this article that the hardening process of the manufacture of lime-sand brick can be greatly facilitated by the addition of very fine sand to the mixture wherever this fine silica is lacking in the natural material. Such an addition will make possible also a shortening of the hardening period. Glasenapp examined the effect of the fine sand by determining the soluble silica and expressing the total effect by the ratio of the soluble silica in per cent. to the per cent. of lime present.

This investigator examined also the reaction of lime upon clay, and found that clay substance was but slightly attacked, and hence is not a suitable ingredient for lime-sand brick mixtures. In fact, it is injurious inasmuch as it was found to surround the coarse particles, thus preventing the action of the lime upon the latter to a large extent. Thus an addition of 5 per cent. of kaolin resulted in a decrease of 25 per cent. of silicic acid as compared with the same mixture free from kaolin. In common red clays this effect is partially neutralized by the presence of quartz and other minerals.

Behavior of Clay in Salt Solutions.

No. 26.

Dr. Hirsch reports experiments made with clay suspended in salt solutions, studying the amounts adsorbed by the various clays. Clays and kaolins adsorb, when stirred up in a salt solution, some of the dissolved salt so that after settling the supernatent liquid has a lower concentration than it had before. Sand and burned clay do not show this phenomenon, while feldspar and marble possess this property to some extent. The amount of salt thus carried down is independent of the time, and the removal of the salt is finished as soon as all of the clay has settled. It is, however, dependent on the kind of clay and kind of salt and the degree of concentration. Barium, lead and aluminum compounds are brought down in considerable quantities, while the amounts of strontium, magnesium, and calcium salts are smaller. The acid of the salt seems to influence the result appreciably. Chlorides, nitrates and acetates are adsorbed more than sulphates. Alkali salts except the carbonates are not adsorbed. The

more concentrated the solution the more salt will be adsorbed, though in a weak solution all of the salt may be carried down. The conditions are more complicated in the presence of several salts, thus the adsorption of barium choride is decreased by the presence of alkali salts, acids and bases, and entirely prevented by aluminum chloride. Sulphates are adsorbed in the presence of caustic alkalies and acids; the alkali chlorides do not seem to have any effect in this connection.

Efflorescence.

Perkiewicz recommends the coating of surfaces with an organic mass, which prevents the crystallization of the salts but burns away in the kiln. This coating he proposes to apply to bricks at the brick machine by a mechanical contrivance. The composition of the mass is not given, but it was said that it was not a flour preparation.

REPORT OF THE CONVENTION OF THE GERMAN PORTLAND CEMENT MANUFACTURERS, FEBRUARY 24th, 1904, AT BERLIN.

The bulk of the results reported were those obtained in the new laboratory built at Berlin by the Society, and maintained at their expense.

Mean Values of Cement Composition and Other Data.

The laboratory has examined nearly all of the German cements, and reports the following results:

	Minimum.	Maximum.	Average.
Silica	20.05	28.82	22.20
Alumina	4.43	9.64	7.39
Ferric Oxide	0.69	5.99	3.00
Lime	57.26	67.64	63.14
Magnesia	0.83	3.55	1.65
Sulphuric Acid	0.70	3.01	1.66
Loss on Ignition	0.95	6.78	2.51
Tensile strength in kg. per sq. cm	16.40	30.7	22.4

The average ratio of silica to alumina was as 1:0.33, the ratio of silica to alumina plus ferric oxide as 1:0.46. The cements highest in lime were the strongest materials.

The director of the laboratory, Dr. Schindler, reported some very interesting results pertaining to the sulphur or gypsum content in cements. It was found that many cements cannot carry more than three percent. of sulphuric acid without showing grave deficiencies.

Professor Gary reports that the Royal testing laboratory has made many experiments, with the determination of the heat changes observed in Portland cement on setting, and has come to the conclusion that each cement shows characteristic heat phenomena re-

sulting in curves, which express the individual character of each material. The Royal laboratory is about to construct a simple apparatus which records the temperature changes automatically.

Dr. Schindler has found by careful micrometer measurements that the changes in volume experienced by a cement on setting stand in some relation with the heat phenomena, resulting in curves very similar to those obtained by Gary. The linear expansion is greatest when setting is being completed.

Dr. Schmidt reported the production of crystalline Portland cement fused in the electric furnace. A cement with 60 per cent. of lime fused to a glassy mass, one with 62 per cent. showed crystals in the interior of the mass, while one with 66 per cent. was crystalline throughout, with a still higher lime content free CaO was observed. The large silicate crystals belonged to the hexagonal system, and contained lime and silica in the ratio of 3:1. High lime cements are improved by fusion, while aluminous cements are better when only vitrified. Radium rays indicate no difference between vitrified and crystalline Portland cement.

Dr. Schott reported on the loss of weight observed by heating anhydrous cement clinker in an electric resistance furnace. It was found that cement which had not been stored still showed a loss of 2.9 per cent. when heated to 600°C, 3.2 per cent. when heated to 900° and 5.9 per cent. when heated to 1525°C. From this it appears quite definitely that the cement contained free calcium oxide, and the expulsion of carbon dioxide begins probably at 600°C.

Cramer reported the destruction of a cement mortar used in a drainage sewer, owing to the absorption of sulphuric acid from the bricks. The latter contained .9 per cent. of gypsum, which was leached out and brought into the mortar, resulting in an accumulation of sulphuric acid reaching 20 per cent., which, of course, destroyed the cement.

Swelling of Plaster Mortars.

Dr. P. Rohland.

This trouble is due to the solubility of the di-hydrate, $CaSO_4$ 2 H_2O, which is increased by the presence of salts like sodium chloride. The presence of the latter tends to produce calcium chloride and sodium sulphate, and results in the production of efflorescence. The remedy is the use of any means which decrease the solubility of the di-hydrate, especially the use of dense mortars, with the smallest amount of water possible.

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OF THE

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VOLUME VII—PART III

Containing Papers and Discussions Read at the Meeting Held at Birmingham, Alabama, Jany. 30 and Feby. 1, 1905, With Some Other Contributions.

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THE CERAMICS OF THE LOUISIANA PURCHASE EXPOSITION.

BY

S. Geijsbeek, St. Louis Mo.

INTRODUCTION.

The Ceramic exhibits of the Louisiana Purchase Exposition, held in St. Louis, in 1904, were in a sense the best which had ever been brought together for such purposes. The foreign exhibits proved especially instructive for the American Ceramic amateur and manufacturer, and they demonstrated plainly the great advance which foreign countries still have over us in the manufacture of finer ceramic products.

The leading American ceramic manufacturers were well represented with the exception of the whiteware potteries. In the coarser grades of ceramic ware we have practically no competition from abroad, and our products are just as good and sometimes better than foreign made. In the field of refractories we are steadily using better fireclays, and our wares compare favorably with any imported products. In faience we are showing just as good work as any foreign country can produce. In terra cotta we are doing excellent work. In finer ceramics we hardly exist, but the attempts have been many, and gradually we will get a hold on this branch of the pottery industry.

The advance of technical ceramic education was shown by several exhibitors, and is a step in the right direction.

In preparing an article like this, we can follow several ways in describing and reviewing the exhibits. First, we might review the countries and states, with their exhibitors, as a nationality, and secondly, we might describe the whole exposition by classification of the different materials and products.

In the first case we obtain a comprehensive idea as to what each country can do without comparison as to the merits of the particular countries, while by the second method, we can make a direct comparative review of all exhibits in the same classification.

In the following review we have taken the second method as being in our estimate the better one, and have adopted the following classification:

Part I. GENERAL ARRANGEMENT.

Part II. EDUCATIONAL CERAMICS.

Part III. RAW MATERIALS, MACHINERY, KILNS, PYROMETERS AND ACCESSORIES, CHEMICAL OXIDES AND CERAMIC COLORS.

Part IV. BUILDING CERAMICS.

(a) *Plain building products:*
Building brick,
Paving brick,
Sewer pipe,
Roofing tile.

(b) *Decorative building products:*
Enameled brick,
Terra cotta,
Encaustic and vitrified tile,
Structural faience.

Part V. REFRACTORY CERAMICS:
Firebrick,
Gas retorts,
Glass pots and tank blocks,
Assayers Supplies.

Part VI. POTTERY:
Earthenware,
Faience,
Stoneware,
Whiteware,
Porcelain.

Part VIII. CONCLUSIONS.

All exhibits are described by countries in alphabetical order.

PART I. GENERAL ARRANGEMENT

In studying ceramics at the St. Louis Fair, it was necessary to have a good conception of the location of all exhibition palaces. There was certainly no other industry scattered in as many buildings, and this even in spite of the efforts of the National Brick Manufacturers Association, under the leadership of Prof. H. A. Wheeler, to concentrate American Ceramics in one building. This effort was partly successful as far as the coarser grades of ceramic ware were concerned, and the exhibits displaying these products were located under the name of "Clay Industries Exhibit," in block 20, Mines and Metallurgy Building.

The materials and products embraced in the groups as classified above from part II to part V, inclusive, were for the greater part located in the same building as the Clay Industries Exhibit, while Part VI, "Pottery," was scattered in about eight different buildings. There were pottery exhibits in the Varied Industries, Manufacturers, Liberal Arts, Fine Arts, Educational, Electricity, Horticulture, and Anthropology and State Buildings.

This state of disarrangement plainly indicates that the potters make a distinct dividing line between their products and the raw materials from which their products are manufactured. It also shows that in order to make a collective exhibit of the pottery industry, in connection with other ceramic products, there must be drawn closer lines than those existing today.

PART II. EDUCATIONAL CERAMICS.

The exhibits which we value from an educational standpoint are those made by clayworking schools and universities having a ceramic department, as well as exhibits which show details of manufacture or manufacturing processes in fact. We find the foreigner in the lead as far as schools are concerned, and this is the more to be regretted, as this country has several institutions which in quality rank with the best foreign schools in ceramics.

AUSTRIA. Austria showed by means of samples of

pottery, tiles in plain and decorative designs, what its government institutions are doing to help the ceramic industry. The Imperial Royal Schools of Applied Arts, of Vienna and Prague, and the State Schools for Arts and Crafts of Teplitz and Bechyn, both in Bohemia, gave good illustrations of the products of their ceramic departments in both technical and artistic results.

France and Germany did not show anything in the line of educational ceramics, but as these two countries at the same time maintain government factories, the exhibits of these plants could be construed as being educational also. We will, however, describe these exhibits under the pottery division.

JAPAN. The best exhibit under this classification was made by the Japanese Government. The departments of ceramics of the University of Ishikawa-Kenand, of Tokio and the Arita Art and Industrial school of Saga-Ken showed their plan of ceramic education. It is rather astonishing to notice that the Japanese, being such old time potters, have taken the initiative to modernize their ceramic art, and have adopted Dr. Seger's methods in accomplishing these changes.

To find complete tables with burnt glazed samples, marked with chemical formulae and melting points expressed in Seger cones, was certainly a treat even to those who do not think that technical education extends beyond their own horizon.

UNITED STATES. The New York Clayworking School, of Alfred, N. Y., had a pottery exhibit in the Educational Building, which was more of an art than an educational exhibit.

Of the private enterprises which had made very excellent exhibits along educational lines were the exhibits of Mr. Ernest Mayer, of the Mayer Pottery Co., Beaver Falls, Pa., and of Mr. F. W. Walker, of the Beaver Falls Art Tile Co., also of Beaver Falls, Pa. Modeled on the same lines was the exhibit of the Star Encaustic Tile Co., of Pittsburg, Pa. The exhibit of the Mayer Pottery Co. gave

us a systematic idea as to the manufacture of whiteware from the raw material to the finished product. First, we see samples with the analysis of the different ingredients used in the body, further an analysis of the washed body. Then follow the glaze ingredients and the frit. With a plate-mold, green, biscuit and glazed pieces is illustrated the process of manufacture. The sagger body composition, and the methods of setting the ware, are plainly shown. Plain and decorated ware is shown as samples of the product of the pottery. Under and over glaze colors in the ground state, the method of printing and transfering, are all shown in minute details. The whole exhibit gave us a better insight into the manufacture of whiteware than we could have gotten by a personal visit to such potteries.

The Beaver Falls Art Tile Co. exhibit described in the same thorough manner the manufacture of glazed wall and vitrified tiles. First, the different clays from which the tiles are made, were shown, then was illustrated the handling of the tiles in saggers for the biscuit and glaze burns, and finally we found glazed tiles in different colors and shades. The whole exhibit had been arranged on highly instructive lines.

As the practical demonstration of the manufacturing processes of any industry can be considered as being instructive and educational, it would be proper to mention here the working exhibit of the Weller Pottery Co., of Zanesville, Ohio, located in the Mining Gulch and being a miniature pottery in full operation.

Ceramic literature was well represented. The Americans were very strongly in evidence. The "Sprechsaal," of Coburg, Germany, the "Clayworker," of Indianapolis, and "Brick," of Chicago, were the few individual exhibitors.

The Transactions of the American Ceramic Society and the Seger Translation attracted much attention. The N. B. M. A. headquarters exhibit was well arranged.

The "Brickbuilder," of Boston, "Clay Record," of

Chicago, "Keramic Studio," of Syracuse, N. Y., and "Rock Products," of Louisville, Ky., had their current issues on file in the Clay Industries exhibit.

PART III. RAW MATERIALS.

It was not a difficult matter to obtain a comprehensive idea of the raw materials used in the ceramic industry, as they were all, with a few exceptions, located in the Mines and Metallurgy Building. It was natural that the United States should furnish the largest number of such exhibits, and that states like New Jersey, Pennsylvania, Kentucky and North Carolina were well represented. Of the foreign countries, the English and the Japanese were the best as far as the ceramic raw materials were concerned.

Those states in which we find abundant clay materials but which so far have not been used to any extent for manufacturing purposes, had taken special pains to have manufactured products made from such clays by firms of other states, in order to bring out the possibilities of their raw material resources, and thus invite closer attention and inspection by the visitor. The terra cotta entrances of the state exhibit of Kentucky, and the special exhibit of the state of North Dakota, were excellent examples of this character. We will describe these products more closely in the report of the manufactured products. In this chapter we will take the states and foreign countries in alphabetical order, and mention the raw materials exclusively.

Brazil. Judging from the exhibits of Brazil of clays, kaolins, quartz and feldspars, we must consider this country, although naturally quite undeveloped, as having a great future. Some of the clays shown have good plasticity, and the kaolin samples are quite pure. The quartz and feldspar specimens were good. Flack & Co., of Rio de Janeiro, and Com. M. de Paranagua, of Parana, showed the best samples.

Canada. The Dominion of Canada had a collective exhibit which contained several good specimens of clays

and feldspars. The state of Ontario had the most promising samples.

CEYLON. The Ceylon Government had several samples of good white clays, while F. T. Ellawala, of Ratnapura, exhibited clays of good quality and also samples of tiles in which these clays were used.

CHINA. The Imperial Chinese Government exhibit contained quite a few specimens of china clays and decomposed feldspars. The Chinese Engineering & Mining Co., of Tientsin, had several varieties of fire clays which were excellent in quality.

FRANCE. Although France did not show any ceramic raw materials, the exhibit of Francis Laue, of Paris, of bauxite and the process of producing pure aluminum is worth mentioning.

GERMANY. The German glass pot clays, which are so well known in this country, were represented by two firms, the Tonwerk Schippach, of Schippach, near Klingenberg on the Main, and Aug. Gundlach & Co., of Grossalmerode.

GREAT BRITAIN. Judging from the annual importation into this country of English clays, it was not astonishing to see represented so many firms in that line. While the whole exhibit was arranged by the Mining Department of the British Government, the clays and kaolins were well represented. Of the English china clays we will mention, the Devonshire china clays from the mines of N. Abbott, and the St. Stephens china clays, from the Bramwell Mines in Cornwall. Cornwall Stone was exhibited by the last mentioned firm also. Of ball clays we find specimens in all colors, samples of the Fountain Clay Mines, in Kingstegton, best Stourbridge clay from the Amblecote mines in Staffordshire. We found also a variety of clays used for floor tiles and fire bricks. The Gillhead Mines, in Cumberland, and the Ganister Mines, of Yorkshire, seem to be the most prominent.

JAPAN. The Imperial Geological Survey of Japan, working under the Department of Agriculture and Com-

merce, had a very well arranged exhibit of kaolins, feldspar and stoneware clays, and also compounded body mixtures. The samples shown are used in the manufacture of some of the well known typical Japanese pottery and stoneware.

The first samples were the raw materials for making Arita porcelain, (Arita-yaki). They are decomposed, liparite from Arita, Hizen Co., called Izumiyama-ishi, and from Amakusa, Higo Co., called Amakusa-ishi. The decomposed material is white, and the pulverized samples show a fine grain. The sample of the body consists of four parts of the first and one part of the second sample.

Kyoto porcelain (Kiyomizu-yaki) specimens were shown next. Here we find another decomposed liparite (Takahama-ishi), also from Amakusa, Higo Co., further two samples of decomposed granite (Tokiguchi-Gairome and Takao-Gairome) from Tokiguchi, Mino Co., and from Takao, Yamashiro Co., ball clay (Shigaraki-zuchi) from Kinose, Omi Co., and also feldspar samples (Choseki) from Mikuma, Omi Co. Further, quartz samples (Keiseki) from Hiroshima, Sanuki Co., used in the body composition. The body making up this porcelain consists of

Seven parts decomposed liparite (Takahama-ishi),
One part decomposed granite (Tokiguchi-Gairome),
One part feldspar, (Choseki),
One part quartz (Keiseki).
Samples of this body were shown.

Awada stoneware (Wada-yaki) can be made from several different clays, as indicated by the variety of the samples exhibited. Agalmatolite, (Roseki), from Mitsuishi, Bizen Co., a decomposed quartz porphyry, (Rokujizo-Mazetsuchi) from Rokujizo, kaolin (Shiroe-zuchi) from Shimoda, clay from decomposed granite (Nendo) from Shinohara, further a carbonaceous clay (Asamiya-Kibushi) from Asamiya, which are all located in Omi County. A decomposed Aplite (Yada-Mazetsuchi), from Yada, Yamato Co., and another carbonaceous clay (Imayama-Kibishi) by which we think is understood

calcareous clay from Imayama, Yamashiro Co. The sample of the washed, dry body mixture, consists of

10 parts Roseki.
10 parts Mazetsuchi and
15 parts Shigarakizuchi.

Satsuma stoneware (Satsuma-yaki) materials are decomposed andesite, (kaolin), (Kirishima-tsuhi), from Kirishimayama, Osumi Co., another andesite (Bara-tsuchi), from Higashikata, Satsuma Co., and further a silicious tufa (Kasedazuna) from Kaseda, also in Satsuma Co. The washed body samples consist of

Three parts Kirishima-tzuchi,
Eighteen parts Bara-tzuchi,
Thirteen parts Kaseda-zuna.

Awaji stoneware (Awaji-yaki) seems to be manufactured from one single clay deposit, while there was only one sample shown, that of a redeposited clay from a granite formation (Ono-tzuchi) from Ono, Awaji County. The washed sample for the body shows that the clay must contain noticeable quantities of foreign matter.

Kaga porcelain, (Kutani-yaki), was illustrated by several samples of raw material, which all come from the county of Kaga. Here we also find liparite samples, Hanasaka-tzuchi, Gokokuji-tzuchi and Nabetani-tzuchi, from Hanasaka, Gokokuji and Nabetani respectively.

The body consists of five parts of each of the first two samples and three parts of the last named sample.

Aizu porcelain, (Aizu-yaki), was also made from decomposed liparite, which is mined in three places in the county of Iwashiro. The samples are Okubo-ishi from Hongo, Kabuto-ishi, from Oki, and Jari-ishi, from Hongo. The washed body sample consists of three parts of the two first samples and two parts of the last sample.

Seto porcelain, (Seto-yaki), was made from the following raw materials, decomposed granite (Gairome) from Yamaguchi, Owari Co., feldspar and quartz, from Takaoka and Sarunage, Mikawa County, respectively. The composition of the body is 10 parts of decomposed granite, 5 parts of feldspar and two parts of quartz.

Tajimi porcelain, (Tajimi-yaki), also mostly consists of decomposed granite (Tokiguchi-Gairome), from Tokiguchi, Mino County, feldspar, (Choseki), from Ohiro, Mikawa Co., and quartz, (keiseki), from Tsumagi, Mino County. The body is slightly different from Seto porcelain, and is made of two parts Gairome, three parts Choseki, and five parts of Keiseki.

All samples were shown in the crude and washed state, and judging from the many localities from which these samples came, Japan must have an unlimited supply of materials for the manufacture of pottery. Besides these samples which we found in the Mines Building, there was one sample of porcelain clay from Murotami Co., exhibited in the Manufacturers' Building. The price named for this clay was 20 Yen, about $10 per ton, at the mines.

Besides the better class of white clays there were several samples of excellent brick clays; a clay from Yamashirodani, Awa Co., and a sandy loam from Nihommatsu, Iwashiro Co., especially are worth mentioning.

Mexico. Mexico only exhibited three samples of clay, two of which were brick clays from the same locality, Zumpango, and a fairly good kaolin sample from Pinos, state of Zacatecas.

Nicaragua. In its pavillion Nicaragua exhibited a few samples of clay. The Jefatura Politica, of Matagalpa, Jinotega and Nueve Segovia, had a collection of clay samples from all three localities.

United States. In reporting the United States of America we will also take the states alphabetically. In many instances we found the clays of the states exhibited in their state exhibits, and also in the Clay Industries Exhibit, like Georgia, New Jersey, and others. On the other hand, we found that the individual exhibitors had mostly exhibited in the Clay Industries Exhibit only.

Alabama. As a clayworking state, Alabama is only very young, and the exhibition of its clay resources was very limited, in fact, it did not at all show the possi-

bilities of what the state could do regarding the clay-working industries. F. Y. Anderson, of Birmingham, exhibited a sample of kaolin from Fort Payne, DeKalb Co. The Alabama Geological Survey and J. Pierce, of Giun, had samples of kaolin from Chalk Bluff, Marion Co. We did not find any fire clay exhibit nor the products which are used in the iron and steel district of Birmingham.

ARKANSAS. The clays of the state are not developed to any extent, and the few samples of brick and stoneware clays are not very promising. Any data assisting in forming an opinion as to their extent was wanting.

The bauxite exhibits of this state, however, attracted wide attention, and the exhibits of the American Bauxite Co., of Little Rock, with an exceptionally large piece of bauxite, deserved special mention. The Pittsburg Reduction Co., with mines at Perrysmith, showed its bauxite and the finished products of aluminum.

CALIFORNIA. The State Mining Bureau had several good samples of kaolin and clay on exhibition, while many of the counties exhibited samples in lump form. Judging from the many county exhibits, California must have abundant clay resources which are quite undeveloped and unexplored. Not less than twenty-six counties showed clay samples, and while most of them could be used for brick manufacture, several samples show possibilities for the better classes of clayware. None of the clay manufacturers showed any samples of their raw material, nor was there any state survey publication on clay resources.

The Pacific Borax Co., of San Francisco, had borax and boracic acid and other by-products exhibited. As this material is used so extensively by potters, the exhibit was very instructive, as it showed the different methods of obtaining the finished products.

COLORADO. This state showed some very good specimens of fire and plastic clays. The Golden district, in which the principal clay mines of the state are located, was well represented. Geo. W. Parfet, of Golden, showed the different samples of his fire clays, stoneware and plas-

tic brick clays, while the Denver Fire Clay Co., of Denver, had specimens of its fire clays, from which the well known Denver assayers supplies goods are made. The Cresto Clay Co., of Boulder, and the Pike's Peak Brick Co., of Colorado Springs, also showed their raw materials. The Van Briggle Pottery, of Colorado Springs, had samples of its crude and washed clay material.

GEORGIA. One of the few states which had made a special exhibit in the Clay Industries Exhibit was Georgia. The State Geological Survey had large pieces of kaolin, which were very pure and burned to a good white, as was proved by the samples exhibited.

I. Mandle, of St. Louis, Mo., exhibited samples of his Georgia kaolin from Bibb County. With burned and glazed samples of almost any kind of pottery ware, he showed the great use of this grade of kaolin by manufacturers.

ILLINOIS. The state of Illinois does not maintain a Geological Survey, however, many exhibitors were represented in the clay line. We found many brick and stoneware clays, and a few samples of impure ball clays from Union County. Goodman, of Cobden, exhibited several samples of white clay which were badly stained with iron. The Northwestern Terra Cotta Co., of Chicago, had samples of terra cotta clays in the ground state.

IOWA. This state showed that its main clay resources are good for brick purposes. A few samples of stoneware clays were shown, also some fire clay samples. Boone, Hardin, Polk and Webster Counties were best represented.

KANSAS. On account of its natural gas supply Kansas is fast developing its clay resources. The Capital City Vitrified Paving Brick Co. showed samples of its shale; the Coffeeville Shale Brick Co. had also some very good shale samples. Several of the other manufacturers had samples of their clays.

KENTUCKY. Kentucky was one of the states which had, besides the state exhibit, also a display in the Clay Industries Exhibit.

The whole arrangement of these exhibits indicates that the state is rich in clay resources. A terra cotta arch, made from Kentucky clay, was the entrance to the clay section. In cases, well arranged, we found the different clays and burnt samples, and sometimes glazed samples of the natural clay, side by side. While, of course, the brick and fire clays are predominant, the better grades of clays, ball-clays and kaolins were well represented. It is evident that Kentucky will play a very important part in the clay industry at some future date, as the close proximity of these clays to the manufacturing centers will give the state perference over the states further south. The Geological State Exhibit contained over one hundred different clay samples from different localities, which run from kaolin to brick clays.

A sample of kaolin from Hart County was a very remarkable specimen of excellent qualities. Mayfield ball clays were shown by two firms.

In the Clay Industries Exhibit we found a large block of fire clay of the Louisville Fire Brick Co., of Louisville, which was of very good quality.

MARYLAND. The Geological Survey of Maryland had a well arranged exhibit of the various clays of the state, while none of the exhibiting manufacturers had any samples of the clays which they are using. Of the fire clays, the Mount Savage, Alleghany Co., flint fire clays were the most prominent samples.

Of special interest to the clayworker were a set of photographs, showing the various apparatus used in testing road building materials, which are practically the same as those used for scientific clay testing.

MICHIGAN. The clays of this state are mostly used for brick purposes. We did not find any clays suitable for the better grades of clayware. The cement factories made exhibits of the clays and marls used in their products.

MINNESOTA. In the state exhibit we found several samples of clays, also some quartzite. The brick clays are predominant in this state.

MISSISSIPPI. The clays of Mississippi were represented by many samples, which, however, did not show anything that would be suitable for the better grades of clayware. The fact remains, however, that George E. Ohr, of Biloxi, demonstrated by his various shapes of pottery ware that even common clays can be used to excellent purposes.

MISSOURI. In the state exhibit we found only a few samples of the many good clays found in the state. In the Clay Industries Exhibit we found the clays of the state better represented. The exhibit of Fred. Bausch, of St. Louis, represented the typical fire clays in the state, while in terra cotta, sewer pipe and brick clays, many samples were shown. In the Mining Gulch, we found a pavillion where fire clay, sewer pipe and brick clays were specially exhibited by many firms. The Cheltenham fire clays and the shale clays were shown in large specimens.

MONTANA. Only a few brick and fire clays were shown in this exhibit.

NEBRASKA. The state is well provided with good red burning clays. The different samples were exhibited by the manufacturers with their finished products, while the Geological Survey had several samples of clay from the various counties of the state.

NEVADA, like the other western states, has its clay resources not developed to any extent, and while different counties showed good clays suitable for the building and fire brick line, their good qualities were not indicated by any manufactured product.

NEW JERSEY. The state of New Jersey was well represented both in the state exhibit as well as in the Clay Industries Exhibit. Middlessex county had the best exhibit, and also is the greatest shipper and miner of all kinds of clays. We found samples from this county in all grades, kaolins, fire clays, terra cotta clays, also ball clays and sagger clays. Woodridge, Sayreville, and South Amboy are well known representative localities. The exhibit of the New Jersey Geological Survey in the Clay Industries

Exhibit deserved special mention. Here was shown that scientific investigation, and tabulated results are of great value to any state. It is an honor which certainly belongs to the state of New Jersey, it being the first to show to the public, what can be done to advance the clayworking industry of a state, by giving intelligent information in regard to nature's deposits. We found samples of the crude and burnt samples, data about shrinkage in drying and burning, the tensile strength of the clays in the wet and dry state. The burnt trials were burnt at three temperatures, cone 3, 5 and 10.

Chas. A. Bloomfield, of Metuchen, was the only individual exhibitor of the state in clays, but the exhibit was poorly arranged.

Quite interesting was also the only exhibit of its kind —a model of the clay-washing plant of Edgar Bros., of Sayreville.

New York. This state showed only a few clays of minor importance, and was poorly represented so far as the clay resources are concerned.

North Carolina. This state is rich in the better grades of clays for pottery purposes. We found that the state had made a special effort to show the different localities where kaolins are mined. The Harris Clay Co., of Dillsboro, as individual exhibitor, showed samples of its kaolin, which is excellent in quality. They showed the extensiveness of their trade by burnt pieces of all kinds of pottery, tile, enameled brick, from all parts of the U. S., in which their product has been used.

The Geological Survey showed also some very good samples of albite, orthoclose, feldspar and quartz.

North Dakota. The clay exhibit of this state was especially gotten up to show what could be done with the undeveloped deposits of clays in the state. Stark County seems to have a rather unlimited supply of different kinds of clay. The products made from the clays in the state were certainly very interesting to the visitor. It must, however, be borne in mind that the products were all

made in factories outside of the state, further that there was no data whatever giving information how large a quantity of the home clay was used in producing these articles. It is quite possible that these clays, by themselves, could be used exclusively for manufacturing these products, but it might be possible that they were mixed with eastern clays in order to show results, and especially since the well trained eye of an intelligent observer could easily detect the similarity of the products exhibited with those made by some eastern firms.

OHIO. The principal exhibit of clays of this state was made in the Clay Industries Exhibit, while some of the products were also shown in the state exhibit. The exhibits were well arranged, and jars properly labeled give a good idea of the extent of the clay resources of the state. Brick clays, fire clays and stoneware clays are found in large quantities and in different localities. The varieties of the finished products exhibited certainly show that Ohio is one of the largest states in the Union as far as the clayworking industries are concerned.

OKLAHOMA. There are several counties in this state that had samples of clays, which mostly belong to the brick grade. It is possible that there would be found some better clays by increased development of the clay resources.

PENNSYLVANIA. The state exhibit was well arranged, and it showed that good judgment was used in its arrangement. Several forms showed the clays which they are using for their products. Some are giving the analysis, shrinkage, and other data. Several good samples of kaolins were exhibited. The Brandywine Summit Kaolin & Feldspar Co., of Philadelphia, showed not only samples of its feldspar, but also of a kaolin. The Graham Kaolin Co., of Avondale, had good samples of its fairly plastic kaolin. The fire clay miners exhibit fireclays, crude and calcined. The Cambria Fire Brick Co., of Figet, Dixon Woods & Co., of Pittsburg, and the Harbison-Walker Refractories Co., also of Pittsburg, were most prominent.

The localities of several mines were not always given. The clays shown by the Mayer Pottery Co. and the Beaver Falls Art Tile Co., both of Beaver Falls, have already been described under the heading of educational exhibits.

Stoneware clay, of New Brighton, was represented by the exhibit of the Sherwood Bros. Potteries Co., of New Brighton.

SOUTH CAROLINA. The only exhibitor of clay was the Peerless Clay Co., of Langley, which showed kaolin in lump form, with no data whatever, while even the name of the exhibitor was difficult to find.

TENNESSEE. The clay resources of Tennessee have a great future. We learn that many counties possess good clays, and that Henry County is the most prominent, and the heaviest shipper. We not only found good clays from this county, from several localities, in the state exhibit, but the individual exhibit of I. Mandle, of St. Louis, Mo., in the Clay Industries Exhibit, was also evidence of the uses to which Tennessee clays can be put.

In a neat circular this exhibitor gave the analyses of all his clays on exhibition. The various articles from the principal pottery centers are sure evidence that American ball clays are taking the place of the imported ones, and that Tennessee ball clays are leading in that respect.

TEXAS. Although the clay industry of this state is rather limited, the Geological Survey has taken quite a lot of trouble to get a good exhibit of the clay resources. Texas appears to be, according to these samples, a state rich in the better grades of clay. We found many good kaolins, also stoneware and fire clay samples. Special mention should be made of the excellent arrangement of the samples exhibited, with burnt trials and shrinkage data.

UTAH. The clay resources are rather undeveloped as yet. The Utah Fire Clay Co. showed samples of good fire clay, while Millard County and Mr. E. Kendle, of Lehi, exhibited some kaolin samples.

VIRGINIA. The clays exhibited by the state showed,

that while some are of apparently good quality, there has been no effort made to exploit them to any extent. J. C. Kennie, of Charlotteville, exhibited some samples of kaolin and quartz, while the Pinchbeck Mine presented samples of feldspar.

WASHINGTON. Several counties showed clays which are of good texture. The clays used by Seattle manufacturers show very good products.

WISCONSIN. The clays of this state are very interesting. We found the white kaolins of Hersey, Baldwin and Glenwood which deserve special mention. The Hersey deposits have been worked for several years, and the products were shown in crude and washed samples.

We found also samples of the clays used in the manufacture of earthenware pottery at Edgerton.

Wausau appears to have an extensive deposit of quartz and feldspar. The Wausau Quartz Co. had exhibited samples of quartz in different grades and sizes, and S. Weidman, of Madison, exhibited samples of Wausau feldspar. No analysis of the material was given.

WYOMING. This state is like the other western states, quite undeveloped as far as the clay resources are concerned. From personal investigation we know that there are several good fire clay and stoneware clay deposits, but nothing is shown. The only exception was made by G. Fox, of Laramie, who exhibited a well selected sample of Albany County kaolin.

This closes the review of the United States. The states which are not mentioned have no clay displays of any kind. It is to be regretted that states like Indiana, and Florida, whose clay resources are good, had made no attempt to exhibit samples of their clays.

VENEZUELA. Venezuela had exhibited many good samples of clay in the Forestry, Fish and Game Building. The government exhibit contained several specimens of clay from different localities. The kaolin from Margarita was a good sample, while the clay from Puesto Colon was a good brick clay.

Machinery.

It has been stated that the St. Louis Exposition would be an exposition at which the processes of manufacture would be shown to a larger extent than at any former exposition. The clayworking machinery, however, made a deplorable exception to this rule. With one single exception, we did not find any of the numerous firms who are manufacturing clayworking machinery with machines in actual operation. The exception was the working exhibit installed in the Weller Pottery exhibit by the Patterson Foundry & Machinery Co., of East Liverpool Ohio, consisting in a miniature pottery machinery outfit. The only brick machine, but not in operation, was installed in the Machinery Building, and was exhibited by the Reliance Machine and Tool Works, of St. Louis, while the Williams Patent Crusher and Pulverizer Co., of St. Louis, exhibited a Williams Pulverizer in the Clay Industries Exhibit. We found further in the same section the American Clayworking Machinery Co., of Bucyrus, Ohio, who had a large working model of their auger machine and represses, with cutting table. The same firm showed also a complete line of manufactured products made by its machinery, which collection was a credit to the firm. Other machine people who had small working models were: The Fernholtz Brick Machinery Co., of St. Louis; the C. W. Raymond Co., of Dayton, O.; and the Scott Mfg. Co., of Keokuk, Iowa, which were all located in the Clay Industries Exhibit.

Kilns and Muffle Furnaces.

CHINA. The Chinese Government showed a wood model of a pottery from the Swatow district, in which the square kiln is the essential feature. It illustrated more the typical kind of factory than the details of manufacture.

GERMANY. In the German section, in the Electricity Building, we found a 1:10 scale drawing, with details of a three story round porcelain kiln as in use by the Royal Porcelain Factory of Berlin.

UNITED STATES. We found in the Clay Industries Exhibit a model of a continuous kiln exhibited by Carl Cebula, of St. Louis. The Weller Pottery, of Zanesville, Ohio, had a small pottery kiln, but not in operation. The Mitchell Firebrick Co., of St. Louis, had erected part of a small size down draft kiln, illustrating the use of their fire brick material for kiln building purposes.

In testing appliances we found several exhibitors. The Braun Co., of Los Angeles, showed several of its test muffles in operation. The Pelton & Crane Co., of Detroit, Mich., had an electric muffle furnace in operation, and Charles Engelhard, of New York, exhibited the Heraeus platinum foil electric muffle furnace, in two styles.

Pyrometers.

ENGLAND. Henry Watkins, of Burslem, had a complete set of his heat recorders on exhibition. These recorders are simply blocks of very refractory clay, with five circular recesses sunk into the top. In these recesses are placed little tablets of fusible material, of definite composition and melting point. These slabs are placed in the kiln and are not removed nor examined until after the kiln is drawn. The main objection to these recorders is that they can not be examined while the kiln is burning, and only record the actual heat of the burnt kiln.

GERMANY. The Royal Berlin Porcelain Factory exhibited several slabs with unburnt and burnt Seger cones, which range from cone 022 to cone 36. Hartmann & Braun, of Frankfort, o. Main, and Siemens & Halske, of Berlin, showed several styles of pyrometers on the Le Chatelier principle, and a self recording instrument on this principle attracted special attention.

UNITED STATES. In the Clay Industries Exhibit we found Charles Engelhard, of New York, showing a full line of his Heraeus Le Chatelier pyrometers, who also had several of these instruments at the U. S. Geological Survey Coal Testing Plant, the Pennsylvania Locomotive Testing Plant, and other places on the grounds, in actual operation.

Ernest Mayer, of Beaver Falls, Pa., showed unburnt and burnt Seger cones of his own make, which are used in his pottery kilns.

Ceramic Oxides, Over and Underglaze Colors.

It was gratifying to observe that in this line of ceramic materials the principal countries were well represented, and in every case the best firms had made exhibits.

FRANCE. France was represented by Lacroix & Co., and Poulenc Freres, both of Paris, with a full line of oxides and colors.

GERMANY. W. Perkiewicz, of Ludwigsberg, illustrated in a neat exhibit his patented process of obtaining good red brick without the use of pigments or engobes.

GREAT BRITAIN. Wegner Ltd., of Stoke upon Trent, had a well arranged display of oxides, over and under glaze colors, also glazes for pottery and enameled bricks.

UNITED STATES. The Roessler & Hasslacher Chemical Co., of New York, showed in part of their exhibit the ceramic colors for which they are so well known. W. Hasburg, of Chicago, had a good display of his Roman gold for pottery decorating, with patent celluloid covering. The Ricketson Mortar Color Co., of Milwaukee, Wis., had a nice exhibit of the different stains used for brick mortars in the Clay Industries Exhibit.

Resume on Part III.

Inasmuch as the clay deposits are the most essential features of the ceramic industry, we are of the opinion that there has not been shown enough intelligence by exhibitors in attracting that interest in the visiting public of an exposition, which is essential to the further establishment and advance of the clayworking industries.

While many exhibitors of finished products showed a specimen of their clay—in some cases only as big as a mail sample—they did not give any data or illustrations

as to what process and system of mining and mixing has been employed.

The geological surveys of the different states have shown that they have the interest of the clayworker well at heart, and if all clay producing states would publish reports in the thorough manner of some of the recent state publications, the clayworker and the public at large would be greatly benefitted. A published report, which shows that the survey has no actual knowledge of technical clayworking, might just as well not been published at all, as it will only create false impressions so far as the clay resources are concerned.

The exhibits of the foreign countries were good, taken into consideration that clays as an export article do not come into much competition. The English exhibit in that respect could have been better arranged, but inasmuch as the importation of English clays in this country is falling off, the interest taken in the exhibit was not very large. Japan made a good display, and it was as thorough an exhibit as any foreign country would want to make.

The few individual clay dealers who made exhibits of their different materials, did make a good impression as far as the technical problems of their work are concerned.

That clay specimens will be found at future expositions goes without saying, and taught by recent demonstrations, we would suggest to future exhibitors to bear in mind that a sample of clay, no matter how good it might be, is of no value to an investigating public, if it is not accompanied by a complete or rational analysis, a piece of the burnt material, preferable at several different temperatures, and if possible other data in regard to shrinkage, plasticity and other essential features, which would indicate the value of the deposit.

If some of the magnificent displays of gold, silver, copper and other ores from the different countries and states had not been labeled in such thorough manner, with their approximate value and other data, their magnitude would have been lost, and the results of those magnificent

exhibits would have been reduced to a feeling of lost time and value, and a waste of unappreciated efforts. To some extent we observed this same feeling when studying the clay resources of the world at the St. Louis Exposition.

In the departments of machinery, kilns, pyrometers, ceramic chemicals and colors the exhibits, with the exception of the pyrometer exhibits, were few and far between. It was rather a pity that exhibits of this nature are always more or less erratic, as very good and intelligent exhibits could be arranged in a simple manner. The French exhibit of Poulenc Freres, of Paris, was a good illustration of what could be done in that respect.

PART IV. BUILDING CERAMICS.

In this section we will endeavor to give a brief description of the ceramic products which belong to the building class. In doing so we will separate the plain from the decorative grades, and make a special heading for each part. It will be appreciated that it is rather hard to judge the coarser grades of the ceramic industry, inasmuch as in many instances we only find a few selected bricks, drain tile, sewer pipe or roofing tiles. In such cases we can only mention the fact that the material was exhibited. Unless otherwise mentioned, all exhibits were located in the Mines and Metallurgy Building.

A. Building Brick, Paving Brick, Sewer Pipe and Roofing Tile.

ARGENTINE. De Filippi Longhi & Co., of Buenos Ayres, exhibited pressed bricks which were of good quality, and must be considered as specimens used in that city for building purposes.

BRAZIL. In the Brazil Pavillion, located in the court of the Varied Industries Building, we found an exceptionally good exhibit, for a foreign country, of the common grades of the clayworking industry.

Several good red pressed bricks were shown by different firms from Paulo, Amazonas and Parana. Sewer pipe

and drain tiles were also exhibited. Paving brick were shown by Estevo & Co., of Minas Geraes. We also found good roofing tiles of the interlocking system.

BULGARIA. Izida Cie., of Sofia, showed some fine pressed, cream colored brick, and salt glazed sewer pipe.

GREAT BRITAIN. Doulton & Co., of London, showed in the Liberal Arts Building several excellent, large sizes of salt glazed sewer pipes in connection with their chemical stoneware exhibit.

MEXICO. Dry pressed, repressed, and hand made brick were exhibited by Mexico in great varieties.

SIAM. In the Manufacturers' Building, McLean & Co., of Bangkok, showed good, pressed, red and buff bricks, which were machine made.

U. S. OF AMERICA. The states are taken alphabetically.

ALABAMA. The Graves Brick Co., of Birmingham, exhibited a good quality of pressed brick, while the Southern Sewerpipe Co., also of Birmingham, showed several sizes of nearly vitrified sewer pipe of a dark color. The Coaldale Brick Co., of Coaldale, had several specimens of vitrified paving blocks.

ARIZONA. Two firms had exhibited their brick products, the Mansfield Pressed Brick & Terra Cotta Co., of Mansfield, and the Clark Pressed Brick Co., of Malvern. The products were of good quality.

CALIFORNIA. In order to show the building materials of the state an arch was erected in which the different building materials, found in the state, were used. Granite, lime and sand stone, pressed brick and terra cotta were well represented. Some good shades of white and colored brick were shown. We are unable to give proper credit to the various exhibitors, as the labeling of this exhibit was very poor. Many of the counties mentioned under raw materials had also bricks exhibited, which were manufactured from the clay samples shown.

COLORADO. In show cases, neatly arranged, we found several brick products. The Golden Pressed Brick

Co., of Denver, had samples of different colors and shades of their bricks. The Cresta Clay Co., of Boulder, had good samples of red bricks.

GEORGIA. The Bibb Brick Co. was the only exhibitor with a few samples of bricks in the Clay Industries Exhibit.

ILLINOIS. The Purington Paving Brick Co., of Galesburg, and the Alton Paving & Brick Co. were both exhibitors in the Clay Industries section. Rock faced pavers, neatly laid in colored mortar, formed the walls of these exhibits. In the state exhibit we found the Illinois Hydraulic Press Brick Co., of Collinsville, the Monmouth Mining & Milling Co., of Monmouth, with brick and sewer pipe samples.

The National Fire Proofing Co., of Chicago, exhibited a steel frame section with fire proof construction, in the Manufacturers' Building.

IOWA. This state had not only many exhibitors of common clay products in the Mines Building, but also a collective ceramic exhibit in the Manufacturers' Building. The collective exhibit was better arranged for the single exhibitor. In the state exhibit the bricks were used for making panels, which served as walls for the exhibit. The Platt Pressed Brick Co., of VanMeter, showed excellent samples of its brick, while the Mason City Brick Co., of Mason City, had building brick and drain tile. The Iowa Brick Mfg. Co., of Des Moines, exhibited paving brick and sewer pipe. The leading Iowa manufacturers were represented in both exhibits.

KANSAS. The brick exhibits of this state were well arranged, and the efforts made to make a representative exhibit of the clay industry of the state, even if they were only manufacturing the coarser grades of ware, were very successful. Some twenty brick concerns had samples of their products, ranging from a good red brick to a paving brick. In the center of the exhibit in the back ground, we found a mantel of ornamental brick made by the Coffeyville

Vitrified Brick and Tile Co., of Coffeyville, which was an excellent piece of work.

KENTUCKY. Part of the wall around the state exhibit was built of brick and sewer pipe, products of different factories of the state. F. Bannon & Son, of Louisville, made an excellent exhibit of sewer pipe and paving brick. The Hydraulic Brick Co., of Louisville, showed very good pressed bricks. Special mention is to be made of a draintile made by hand in 1850, which was exhibited by W. T. Keates, of Owensboro.

LOUISIANA AND MINNESOTA. These two states had only a small exhibit of their clay products. The Twin City Pressed Brick Co., of St. Paul, showed good bricks, while the Red Wing Sewer Pipe Co., of Red Wing, Minn., had samples of good sewer pipe.

MARYLAND. The brick industry of Maryland was well represented in the state exhibit. The leading manufacturers had sent a good collection of their products. The exhibits were well arranged and properly labeled. The Baltimore Brick Co., of Baltimore, presented good pressed bricks, while the Edwin Bennett Roofing Tile Co., also of Baltimore, showed good roofing tiles.

MISSOURI. In the state exhibit we found a small pavillion which represented the clay products of the state. The base was of pressed brick, in different colors, from the Hydraulic Press Brick Co.; the columns, caps and coping were terra cotta made by the Winkle Terra Cotta Co., and the roofing tiles were furnished by the Mound City Roofing Tile Co., all of St. Louis.

As individual exhibitors in pressed brick, the exhibit of the Hydraulic Press Brick Co., of St. Louis, was the most elaborate and the best exhibit in the brick line. In the center of the Clay Industries Exhibit we find a two-story brick pavillion, in the renaissance style, of architecture. The main kind of brick used is of an iron speckled brown color, the trimmings are light buff and gray. Enameled bricks are used in a very moderate but effective manner. The steps leading into the pavillion are of

mottled gray, hard burned brick, with rounded corners, which made an excellent material for that purpose. On the inside we found the ornamental features of pressed brick in four mantels, each different in design and color. An exhibit like this illustrates the possibilities of modern brick architecture. It is a credit to the firm which undertook the task of educating the people to the advantages of brick as a building material, effective in design, and harmonious in color.

The sewer pipe industry of the state was represented by the Evens & Howard Fire Brick Mfg. Co., and the Laclede Fire Brick Co., both of St. Louis.

The first firm had a full line of sewer pipe exhibited in the Clay Industries Exhibit, while a neat pavillion with sewer pipe columns and fire brick walls was shown in the Manufacturers' Building.

The Mound City Roofing Tile Co. had also a pavillion in the Clay Industries Exhibit showing the different styles of their tiles.

Montana and Nebraska. The former state only showed bricks from one firm, while the latter had several exhibits of good building bricks.

New Jersey. Quite a few of the leading brick manufacturers had made exhibits. The Atlantic Brick Co., of May's Landing, exhibited excellent front brick, while the Kingsland Brick Co., of Kingsland, had exhibited building and paving bricks.

New York. The clay industries of Alfred were represented by a pavillion in the state exhibit, in which the brick pillars were made of brick from the Alfred Clay Co., while the roofing tiles were made by the Celadon Roofing Tile Co. Among the other exhibitors of brick we will mention the Jamestown Shale Paving Brick Co., of Jamestown, and the New York Hydraulic Brick Co., of Canandaigua.

North Carolina. The state exhibit showed a few samples of the brick manufactured by the Asheville Brick & Tile Co, of Ashville, and the Caraleigh Brick Co.,

of Raleigh, which were of fairly good quality considering the resources of high grade clays in the state.

NORTH DAKOTA. The Dickinson Fire and Pressed Brick Co., of Dickinson, had made a very good exhibit of the bricks manufactured from North Dakota clays. Several counties also showed bricks manufactured in their section, without giving the names of the manufacturers. These exhibits showed the possibilities of the state in the building brick line, which is yet quite in its infancy.

OHIO. The brick industry of the state was well represented in the Clay Industries Exhibit. We found several panels of different colors and different makes. The Columbus Brick and Terra Cotta Co., of Union Furnace, the Cleveland Hydraulic Pressed Brick Co., of Cleveland, and others, had made good exhibits, in the building brick line, while in the paving brick branch we find the well known Canton paver, the Metropolitan, as well as brands from the Hocking Valley.

A large 36 inch sewer pipe of the American Sewer-pipe Co., of Toronto, showed the product of that line.

The Cincinnati Roofing Tile Co., of Cincinnati, and the Akron Roofing Tile Co., of Akron, exhibited samples of their products.

OKLAHOMA AND TENNESSEE. Several pressed brick concerns of the first state had made exhibits, which show that the territory has many opportunities for the building line, while Tennessee showed by a well arranged exhibit, that the building brick and the sewer pipe business is well developed. The Knoxville Brick Co., of Knoxville, and the W. G. Bush Brick Co., of Henry Co., showed good products.

PENNSYLVANIA. The Kittanning Fire Clay Co. was well represented in both the state and the Clay Industries Exhibits. We also found the Montello Brick Co. with some very good samples of building brick.

TEXAS. The brick manufacturers showed a full line of their products, and judging from the different grades, the state is well supplied as far as bricks are concerned.

The Thurber Brick Works, of Thurber, the Gainesville Pressed Brick Co., of Gainesville, and many others had made good exhibits.

VIRGINIA. A fairly good exhibit was made by this state. S. G. Allen, of Front Royal, showed good samples of vitrified brick. Other concerns are the Washington Hydraulic Pressed Brick Co., of Alexandria, and the Richlands Pressed Brick Co., of Richlands.

WASHINGTON. For a Pacific coast state, Washington made a good exhibit of bricks and sewer pipe. The Renton Clay Co., of Seattle, and the Washington Brick Co., of Washington, were well represented with different lines of their products.

WISCONSIN. Not very many firms were represented in the state exhibit. Few firms showed drain tile, while the Menominie Hydraulic Pressed Brick Co., of Menominie, exhibited good samples of their brick. Wm. Finnegan, of Green Bay, showed also good samples of building brick.

WYOMING. We find only one exhibitor in this state, the Casper Pressed Brick Co., of Casper.

B. Decorative Building Products.

Enameled Bricks, Terra Cotta, Encaustic Tiles and Structural Faience.

Under this class we find more individual exhibitors with more elaborate exhibits than under the last. The foreigners were also better represented in this class, and while the products differ quite considerably from our own makes, we can form a good idea as to the value of the exhibits.

ARGENTINE. Felix Pedretti & Sons, and B. Spenedi & Bros., both of Buenos Ayres, showed good specimens of mosaic floor tiles. Glazed wall tiles are shown, which are poor as far as the body is concerned, but good in effect, and good soft glazes.

AUSTRIA. In the state building we found mantels in glazed tile and terra cotta, which were made by the Rako-

nitz Chamotte Mfg. Co., of Rakonitz. The design for these pieces was made by the Art School of Prague. The harmony of colors and the light application of modeling has produced excellent effects. Friedrich Goldschneider, of Vienna, exhibited excellent terra cotta figures in the Manufacturers' Building.

BELGIUM. In the Belgium Pavillion we found two well known firms exhibiting all kinds of tiles. Boch Freres, of La Louviere, had four panels set with 10x3 inch tiles, which are over and under glazed in design. Vitrified tiles were also shown, plain and colored.

The Societe Anonyme des Products Ceramiques, of Chimay, of Forges lez Chimay, had a well arranged exhibit of inlaid vitrified floor tiles. Helman, of Brussels, exhibited large panels of decorative tiles, a design of Spring, which showed excellent taste in colors.

FRANCE. In the Manufacturing Building we found the Societe des Produits Ceramiques et Refractaires, of Boulogne sur Mer, which had a very good exhibit of vitrified tiles in single and encaustic design. We also found that the crystalline glazes are used by this firm for decorative purposes on tiles.

Jules Loebnitz, of Paris, exhibited a terra cotta mantel, also tiles which were very strong in relief, but the whole exhibit showed lack of harmony between design and decoration.

Renè Sachot, of Montereaun, exhibited a terra cotta mantel, with lustre glaze finish, and while the technical part could be judged correct, the decorative effect is very poor.

Alphonse Hanne, of L'Isle Adam, had the best exhibit in terra cotta figures, which were decorated in color in exact reproduction of life, and the effects obtained were excellent.

Of the other exhibitors we will mention, Hache & Co., of Vierzon, and Janin Frères & Guerineau, of Paris, who exhibited both large tiles and terra cotta figures.

GERMANY. In the Mines Building we found a very

good exhibit of tiles by the A. G. Norddeutsche Steingutfabrik, of Grohn, near Bremen. The exhibit was arranged in pyramidal shape, the tiles were set with borders, each field representing some well known locality. The color effects were very good, and the tiles were technically perfect.

In the Varied Industries Building we found Villeroy and Boch, of Mettlach, who had furnished the tiles and terra cotta walls of the room in which the ceramic products are exhibited. The glazed terra cotta was of a blue to blue green effect, and the decorative designs were correct in every respect. In tiles we found the same effect, well in harmony with the balance of the decorations.

Wessel's Wand Platten Fabrik, of Bonn, furnished tiles in mottled and crystalline glazed effects, which were distributed throughout the German section for wall decorations. The effects were good.

We found also eight large panels of the Waechterbacher Steingutfabrik, of Schlierbach, in different glazed effects, which were excellent.

The Marienberger Mosaikplatten Fabrik, of Marienberg, exhibited its products in two places, and they were used to illustrate the German art of interior decoration. The Gail'sche Dampfziegelei, of Giessen, exhibited on the same principle a mantel of enameled brick, which was good in design and color.

In this connection we will also mention the Tonwerke Kandern, of Kandern, who had exhibited terra cotta mantels in color designs, which were executed according to the design of Prof. Max Laeuger, of Karlsruhe. The main exhibit of this German art potter we will review under the head of pottery.

Great Britain. In the Varied Industries Building we found the tile and terra cotta exhibits of the English firms. The best exhibit in this line was from Minton, Hollins & Co., Ltd., of Stoke-upon-Trent, who exhibited an elaborate terra cotta fountain, in green glazed terra cotta, with glazed tile floors. The whole was well designed,

and well executed. The tile panels exhibited by the same firms were of the same good character.

Sherwin & Cotton, of Staffordshire, exhibited tiles and glazed bricks for interior decoration. The exhibits of A. Meakin, Ltd., of Tunstall, and of G. Wooloscroft & Son, Ltd., of Staffordshire, were small, and some of their tiles were badly crazed.

The Pilkington Tile Co. exhibited some very nice tile panels in the Art Palace.

In the application of tiles for practical purposes we like to call attention to a chart or map exhibit of the railroad system of the North Eastern Railway, in the Transportation Building. We find here a six foot square frame, with 6″x6″ white glazed tiles on which the map of this railway system was painted. We presume that such maps are used in the various stations along the lines of this railroad. The name of the firm which executed this map could not be obtained.

Italy. Graziano Appiani, of Treviso, was the only exhibitor of that country in tile, located in the Varied Industries Building. The exhibit was well arranged, and the variety of the tiles shown was great. The extreme thinness of some of the floor tiles, which were perfectly straight, was remarkable. We found also mosaic tiles in various colors, and the exhibit was technically perfect.

Cellai & Dini, of Florence, exhibited some large terra cotta figures, which were excellent in execution.

Mexico. In the terra cotta line we found some excellent work done by M. R. Calderon, of Toluca, exhibited in large decorated terra cotta vases, and by Heraclio Farias, of Gaudalajara, who sketched Mexican life in clay relief.

Netherlands. The Dutch tile manufacturers were well represented, and the application of tiles for interior decoration is well advanced in that country. The largest tile scene of the whole exposition we found in the exhibit of the Delft'sche Aardewerk Fabrik, "De Porceleyne Fles," formerly Joost Thooft & Labouchere, of Delft.

It is executed in Delft blue and represents some historical Dutch Oil painting. We found also smaller tile paintings, which fully illustrate the large demand for that class of work for interior decoration. In the same exhibit we found a vitrified biscuit body which is used by the firm for exterior terra cotta purposes, and which, when fired with vitrified colors, makes an excellent building material.

The Royal Manufactory of Porcelain and Pottery, "Rozenburg," of the Hague, exhibted also large tile frames. The paintings are in different colors, and the effects are true reproductions of oil paintings. Some very good results were obtained with Rembrand light effects.

The largest exhibit of small tiles was made by Gebr. Tichelaar, of Makkum. These tiles are all decorated in plain blue or sepia colors, and produce good effects.

Of the other exhibitors who showed good tiles in decorative design are to be mentioned: Wed. N. S. A. Brandtjes & Co., of Purmerend, and Plateelbakkery Delft, of Hilversum.

PERSIA. Persia showed some old tiles in turquoise blue, which, however, were more relics than recent products.

UNITED STATES. Taking into consideration the many exhibitors in this class, not only as individual but also as state exhibitors, we will take the firms, by states, in alphabetical order.

CALIFORNIA. In the state exhibit we found nearly all exhibitors. Gladding, McBean & Co., of Lincoln, had terra cotta in the state arch; they also exhibited pieces of their various shades of terra cotta; N. Clark & Son, and the Steiger Pottery & Terra Cotta Co., both of San Francisco, also exhibited a few pieces of their products. While this Western terra cotta is apparently not as good as the Eastern goods, it must be admitted that the prospects are bright for reaching a good quality of terra cotta in the Coast states. The Pacific Art Tile Co., of Los Angeles, exhibited panels of glazed and vitrified tiles, which are good in quality.

CONNECTICUT. The Hartford Faience Co., of Hartford, exhibited in the Clay Industries Exhibit, tiles and a terra cotta mantel which was a credit to the firm. The "Sun Worshippers" will long be remembered as an execution in clay which shows the possibilities of plastic relief in matt glaze effects.

ILLINOIS. One of the best exhibits in glazed terra cotta was made by the North Western Terra Cotta Co., of Chicago, with a pavillion in the center of the Clay Industries Exhibit, in white enameled terra cotta, with a brown glazed base, and matt green dome, the whole representing an architectural feature, which is artistically in advance of anything shown, and technically perfect. The work was designed by Mr. Fritz Wagner, Secretary of the Company, and the technical execution was in the hands of Mr. A. F. Hottinger.

Three groups of figures surmounted each corner, and an eagle with spread wings completed the top of the dome. In the interior we find four panels in matt glaze effects. The dome is in matt sky blue, with golden stars, and the whole is a splendid piece of work. The same firm has two red flashed columns, at one of the entrances of the Clay Industries Exhibit, which showed the possibilities of that class of work for terra cotta purposes. We also found a full line of terra cotta samples illustrating the different colors and imitations of stone which the firm puts on the market.

The American Terra Cotta & Ceramic Co., of Chicago, exhibited in the Mines Building large terra cotta vases, in green matt finish. A terra cotta panel with a landscape in vitrified colors produced an excellent effect.

The Tiffany Enameled Brick Co., of Momence, had erected a square pavillion which was built entirely of its enameled products. The general style was white and blue, using matt glazed brick, which produced an excellent effect. A case containing all shapes and styles of brick gave an idea regarding the different products the firm is manufacturing.

KENTUCKY. The terra cotta arch erected by the

state, made from Kentucky clays, showed the possibilities of the clay resources, and it will only be a short time when terra cotta will be manufactured extensively in the state.

The Cambridge Tile Co., of Covington, had erected a neat, instructive exhibit. The walls were white, with colored borders, while the floor was in part white and vitrified, and in part consisting of mosaic tiles. The bathroom at one end of the exhibit fully illustrated the use of this class of material for bathroom purposes. As a feature of the exhibit is to be mentioned an Indian head in mosaic, which was a perfect piece of work.

MARYLAND. Andrew Ramsey, of Mount Savage, exhibited different panels in the state exhibit of good enameled bricks.

MASSACHUSETTS. The Grueby Faience Co., of Boston, exhibited in the Varied Industries Building, and showed the application of faience for building purposes. While it is, of course, to the advantage of firms engaged in that line of work to adhere to their original class of products, faience, the recent departure of this firm from pottery to structural material can only be indirectly classified as structural faience while, in fact, the product is glazed terra cotta.

Grueby showed a line of work which was executed for the New York Subway. It is heavily decorated in matt glazed colors, and while the effects on single pieces are good, the harmony, on the whole, is sometimes wanting altogether. In mantel work, the designs and decorations are more in harmony with the general output of the plant. A light green, glazed, perforated railing encloses the exhibit, which makes a good impression from a distance.

MISSOURI. The Hydraulic Pressed Brick Co., of St. Louis, showed in its pavillion, already described, different classes of enameled and glazed brick. They have a green glazed brick in which the iron has produced a mottled effect, which is very pleasing.

The Winkle Terra Cotta Co., of St. Louis, had a splendid exhibit in the Manufacturers' Building, which must

be considered as one of the best exhibits in the terra cotta line. It is conventional in design, with figures symbolizing Sculpture, Architecture, Chemistry and Mining, while the dome is surmounted by a figure representing Atlas bearing the world. It is monotone in color, which represents Bedford stone, in vitrified slip finish. The pavillion is surrounded by a ballustrade of gray speckled terra cotta, with heraldic lions as entrance posts. The floor of the whole exhibit consists of vitrified gray and white tiles, with a red border. The design of this pavillion was made by Mr. Ernest A. Maddison, chief draftsman. We found also samples of glazed terra cotta in different colors and finish. A terra cotta column, made in one piece, measuring eight feet in height, gives an idea of the ability of the firm to master technical problems.

The St. Louis Terra Cotta Co., of St. Louis, furnished one of the entrances to the Clay Industries Exhibit in a pair of cream colored columns. The shafts are fluted and have ornamental caps. The color is very uniform, and the technical execution is very creditable.

New Jersey. The Blue Ridge Enameled Brick Co., of Newark, had made a very nice display of its products. A court surrounded with a wall in which everything is of enameled brick, presented an excellent example as to the uses of these products. The glaze finish of the product is perfect, and while mostly in bright finish, samples of matt glazed bricks were also shown. A large case exhibiting all colors and shapes made by the firm forms the back ground of the exhibit.

Sayre & Fisher, of Sayreville, had exhibited their enameled bricks in one of the panels of the railing of the Clay Industries Exhibit, while the American Enameled Brick Co., of South River, furnished the base, in enameled brick, for terra cotta columns from the South Amboy Terra Cotta Co., of South Amboy.

The Excelsior Terra Cotta Co., of Rocky Hill, has furnished the columns for the main entrance of the Clay Industries Exhibit. The design and finish are good, and the glazed surface is a white dull matt of pleasing effect.

The Perth Amboy Terra Cotta Co., of Perth Amboy, had furnished two columns for another entrance of the Clay Industries Exhibit. The columns are sandblasted, producing a dull surface with rough and pitty imperfections. The mechanical execution of the columns is poor, as the two pieces of the shaft do not fit together.

The Trent Tile Co., of Trenton, exhibited its product in connection with the sanitary ware exhibit of the Trenton Potteries Co., in the Manufacturers' Building.

OHIO. In the Clay Industries Exhibit we found in the Ohio section a few tiles made by the American Encaustic Tile Co., of Zanesville, and also a case of tiles made by the Ohio Tile Co., of Hamilton. The tiles used in the Ohio state building were furnished by the Mosaic Tile Co., of Zanesville. In the Varied Industries Building we found a small exhibit representing a mantel in green matt glazed tiles from the American Encaustic Tile Co., of Zanesville, which also showed some tile panels in a dark red, matt glaze.

The Rookwood Pottery Co., of Cincinnati, showed in the Clay Industries Exhibit some mantel effects in matt glazes which are excellent. They also have done work for the New York Subway, which is exhibited in panel work in various colored matt glazes.

PENNSYLVANIA. The exhibit of tiles of the Beaver Falls Art Tile Co., of Beaver Falls, and of the Star Encaustic Tile Co., of Pittsburg, have already been reviewed under the head of Educational Exhibits.

Wm. Galloway, of Philadelphia, had a nice line of garden vases in different terra cotta colors in the Horticulture Building.

Resume of Part IV.

The exhibits of the building materials suggest many things. In the building, paving brick, sewer pipe and roofing tile branches we find no foreign competition, and consequently we have no comparative exhibits to judge even the merits of our own products in comparison with foreign wares. We can judge the national exhibits in

regard to each other and come to the conclusion that, taking in consideration the extensiveness of this branch of ceramics, the number of representative exhibits is very small. Those firms who did spend energy and money in order to make a showing had splendid exhibits, that impressed not only the Americans but the foreign visitors as well.

Of the decorative building products the terra cotta and the structural faience firms made the best showing. Here we also have hardly any foreign competition, and while we find in structural faience a few foreigners, judging from these exhibits we feel assured that we are able to handle the artistic and technical part of that branch in a most satisfactory manner.

In enameled brick we have actual commercial competition, but the Exposition does not show us that part. No foreigner has made any representative exhibit, while the few American exhibitors made an excellent showing.

In encaustic and vitrified tile we meet a very disappointing feature in regard to foreign and national exhibits.

The foreigners made a feeble attempt to show what they were doing, while the American manufacturers, with one creditable exception, the Cambridge Tile Co., of Covington, Ky., did not make as much as a feeble attempt.

We do not include in this class of exhibits the Beaver Falls Art Tile Co., of Beaver Falls, nor the Star Encaustic Co., of Pittsburg, who made very good exhibits, but more of an educational character than showing the commercial side of the question. It can not be said that the exhibit of the American Encaustic Tile Co., of Zanesville, was a credit to the largest tile manufacturers of this country.

Taking all branches together the exhibits were national in character, and as such we could obtain a good comparison of the few exhibitors. We find upon close examination that as a rule the Western manufacturer produces a better quality of goods than his Eastern competitor.

PART V. REFRACTORY CERAMICS.

Refractory ceramics at the St. Louis Fair were essentially national rather than international in character. The few countries which had exhibited fire clay products did not show the same in very important places, and even among the national manufacturers we missed the most important one.

CHINA. The Chinese Engineering & Mining Co., of Tientsin, showed two grades of hand made fire brick. In a recent test it has been proven that these bricks were of good quality, and we presume that they are used extensively for pottery kilns in that country.

HUNGARY. The Magnesite Co., Ltd., of Budapest, showed a full line of magnesite, in lump and in the calcined form, as well as different shapes of brick made from the same. In the Clay Industries Exhibit we found the same firm represented through their American Agent, Theo. Pfisterer, of New York.

UNITED STATES. The few exhibitors are taken by states.

COLORADO. The Denver Fire Clay Co., of Denver, exhibited in various places a full line of its assayer supplies and fire clay goods. The excellent reputation of these assayer's goods is supported by the actual tests which were made in the Metallurgical Building, in which the ores were tested from the stamp and concentration mills on the grounds.

ILLINOIS. The Argillo Fire Brick Co., of Carbon Cliffs, exhibited a few samples of its bricks. These brick appear to be a medium grade fire brick of good appearance.

KENTUCKY. This state had made an excellent showing in the fire clay line. Not only did we find good exhibits in the state section, but in the Clay Industries section also we found well arranged exhibits. The Louisville Fire Brick Co., of Louisville, had made a good representation. The manufactured products consist in large blocks of locomotive lining, stove tiles, cupalo lining, and

fire bricks. The Ashland Fire Brick Co., of Ashland, and the Tygart Fire Brick Co., of Fullerton, had similar exhibits, but not as complete. In the state exhibit we found also represented the Olive Hill Fire Brick Co., of Olive Hill.

MARYLAND. The fire clay manufacturers of this state were well represented in the state exhibit. The Maryland fire clays have a good reputation, and the products show up well. The Baltimore Retort & Fire Brick Co., of Baltimore, showed a good line of hand made brick, and also a small gas retort and accessories. The Union Mining Co., of Mount Savage, and the Mt. Savage Fire Brick Co., of Frostburg, exhibited a good line of high grade fire brick. The Green Hill Fire Brick Co., of Northeast, and Gardner Bros., of Ellerslie, are both manufacturing a good grade of brick and stove linings.

MASSACHUSETTS. The Presbery Fire Brick Co., of Taunton, had a small but good exhibit of fire clay goods which apparently are of excellent quality.

MISSOURI. The Missouri fire brick industry, located principally in the St. Louis district, was well represented, and had made a most complete exhibit of nearly all the leading firms.

The largest exhibit and the most illustrative one was made by the Laclede Fire Brick Co., in the Manufacturers' Building. It showed the actual installation of two gas benches built in the latest style of gas retort construction. In the Clay Industries Exhibit this firm showed a complete line of all its fire clay products in bricks, linings, and other shapes.

The Parker-Russell Mining & Mfg. Co. had a very neat exhibit in the Clay Industry section. It showed two sizes of gas retorts, and all shapes and sizes of fire clay blocks and fire brick.

The Evens & Howard Fire Brick Co. exhibited a full line of fire brick which are used in gas, zinc and lead smelting works.

The Missouri Fire Brick Co. had erected in the Mining Gulch a full size gas bench.

The Mitchell Fire Brick Co. exhibited a full line of its fire brick, and a special feature of the exhibit was a small kiln shown in half section, illustrating the use of these bricks.

The Mississippi Glass Co. exhibited glass pots in the green and burnt state, also fire brick which are mostly used by the firm in its own glass plants.

The St. Louis Vitrified and Fire Brick Co. also had a nicely arranged exhibit of fire clay products. We found further, exhibits of the Fulton Fire Brick Co., of Fulton, and the Vandalia Fire Brick Works, of Vandalia.

New Jersey. In the state exhibit we found four firms which had made small fire brick exhibits. J. W. Berry, of Woodridge, the National Pyrogranite Co., of South River, and Henry Maurer & Son, of Maurer, are the best representatives with good products.

Ohio. While none of the exhibitors of this state had made an individual exhibit, the collective exhibit of the state was fairly well representative. The Ohio Valley Clay Mfg. Co., of Steubenville, exhibited a glass pot in the green state, and also tank blocks. The Aetna Fire Brick Co., of Oak Hill, and the Toronto Fire Clay Co., of Toronto, had made good exhibits of their products. The Harbison Walker Co., of Portsmouth, and the Robinson Clay Products Co., of Akron, showed only a few samples of their products. The exhibits might have been labeled better so as to give more intelligent information.

Pennsylvania. Cyrus Borgner, of Philadelphia, had made a nice exhibit in the Clay Industries section. The exhibit included fire brick, tuyere fittings, gas retorts, and blocks. The products presented the appearance of being high grade. In the State exhibit we found several fire clay manufacturers with good exhibits. The Harbison-Walker Refractories Co., of Pittsburg, had a very interesting exhibit; the Dixon Woods Co., of Pittsburg, had a special exhibit in tank blocks. Other exhibitors in the fire brick

line were the Westmoreland Fire Brick Co., of Pittsburg, the Delany Fire Brick Co., of Fairchance, and E. E. Mellick, of Retort.

Resume of Part V.

What has been stated in a general way in the resume of part IV applies also to refractory ceramics. The most gratifying feature of the fire clay product exhibits was the fact that we impressed the foreigners, who always had an idea that America did not produce excellent fire clay wares, and that we had to go abroad for our raw materials. It can be stated authoritively that the St. Louis and the Kentucky fire clay manufacturers created an excellent impression upon our foreign visitors, which is an expression in favor of the high grade qualities of our fire clay products.

Few of the exhibitors showed an instructive exhibit, while the majority only made an exhibit of the different shapes and styles which they were manufacturing.

PART VI. POTTERY.

Under this heading we will review all exhibits which belong to the fine ceramics. This class is the most international of all, and we found all the leading countries well represented. Inasmuch as the pottery exhibits were located in so many buildings, we will mention in every instance the location of the exhibit.

ARGENTINE. P. Bennedetto & Bros., of Buenos Ayres, exhibited in the Manufacturers' Building a few earthenware jardinieres with flowing, colored glazes, which produced good effects.

AUSTRIA. The pottery industry of Austria was located in the Manufacturers' Building. Some well known firms were represented, and while the exhibits were not decorative in finish, the wares exhibited were good.

The Dux Porcelain Works, of Dux, Bohemia, exhibited three grades of products. First, we found porcelain with a gray matt glaze, sometimes decorated with gold.

The product was excellent in character and consisted mostly of figures. Further, we found porcelain decorated in a rich cobalt blue color which was applied to vases and trays, and which were very good. The center of the exhibit was an earthenware figure, representing a slave bound to the trunk of a tree. The modeling and finish were excellent.

Riessner, Stellmacher & Kessel, of Turn-Teplitz, Bohemia, had a very good exhibit of Amphora ware. The effects were obtained by an ivory matt glaze, and also by lustre application. A large vase was exhibited with a mottled, matt, colored glaze effect in crackled finish and gold decorations.

Carl Fr. Boseck & Co., of Haida, exhibited a line of Alhambra porcelain in red and dark green over glaze colors, with rich gold decorations.

B. Bloch, of Eichwald, Bohemia, had a very decorative line of porcelain and also majolica jardinieres and specialties.

Robert Pilz and Franz Doerfl, both of Vienna, showed the products of artistic china painting.

Belgium. In the Belgium State building we found the industrial exhibits of pottery ware. Vermeiren Coche, of Brussels, had several cases of very good porcelain, highly decorated with gold relief. A head in matt crystalline glaze was good, while several plates were shown in different designs. La Ceramique de Forges Co., already mentioned under part IV for tiles, exhibited blue and gray decorated stoneware, which was strictly Flemish in design. Boch Brothers, of La Louviere, exhibited majolica in old Dutch design and stoneware vases with crystalline glaze effects. Helman, of Brussels, had a good Flemish stoneware exhibit, and also some crystalline glaze wares.

Brazil. Several firms exhibited samples of their stone and white ware in the Brazil Pavillion. Some of these products were good in quality, but not very rich in design. R. T. C. Rocha, of Minas Geraes, and J. R. Bastos, of Maranhao, had stoneware displays, while Jos. Wolmann

and J. A. Panitz & Irmacos, both of Rio Grand do Sul, exhibited white ware. Vases and specialties made from a red, washed, body, covered with a good soft tin glaze were exhibited by the Society Co-operative, of Parana.

BULGARIA. The Izida Cie., of Sophia, exhibited in the Varied Industries Building a full line of red and yellow stoneware and majolica jardinieres. The yellow ware was effectively decorated with some gold, and the whole exhibit gave a good idea of what this company is able to manufacture for home consumption.

CEYLON. In the Ceylon Pavillion, in a case well arranged, D. B. David, of Galle, exhibited some antique porcelain which was certainly of Chinese origin.

CHINA. In the Liberal Arts Building we found China all by itself. Of modern ceramics we are unable to find much evidence, while historical pottery exhibits were well represented. The Industrial Institute of Peking exhibited a large case with old Chinese porcelain, which was labeled with data of manufacture and prices. Some of these vases had a marked value of $5,000 to $8,000. The Tea and Porcelain Co., of Shanghai, exhibited porcelain of old and recent date. A few vases with Celadon glazes were very remarkable pieces of pottery. Among some of the other exhibitors we will mention Tak Loong, of Canton, who exhibited several dinner sets in true Chinese design.

DENMARK. In simple, store like, arrangement we find the ceramic products of Denmark in the Varied Industries Building. "Royal Copenhagen" is an expression which is familiar not only to the ceramic world, but also to the public at large, and it was therefore not astonishing to find the exhibit of the Royal Copenhagen Porcelain Works, of Copenhagen, the center of attraction. This well known pottery dates as far back as 1760. It was founded by a Frenchman, named Fournier. In 1775 the factory was taken over by the government. It remained government property until 1867, when G. A. Falck bought the pottery from the state. In 1882 an incorporated company under the name of "Aluminia" obtained hold of the

pottery and has been operating it ever since. The pottery is therefore royal only in name and not in ownership. The trademark consists of three parallel, wavy lines in blue, under the glaze, with a crown, representing the Sound, the Great and Little Belts, which are the three sea arms of the country.

The exhibit was well arranged with products of the different periods of its existence. We found reproductions of the old blue underglaze fluted porcelain and samples of ware of the time when the Rococo style was much used for porcelain designs. Then we come to the modern Copenhagen ware in high fire under glaze designs, and as specialties crystalline zinc glazes in white and colored effects.

When we consider the high temperature at which Copenhagen porcelain is burned, cone 22, we are astonished at the results obtained, and come to the conclusion that the technical part is perfect. The harmonious combinations of color, the correctness in design, all give the product an impression of perfection which is at once commanding. A large jardiniere, with a water scene and some birds in the foreground, painted by the artistic director, A. Krog, is truly beautiful. In crystalline glazes the results are very good. Zinc crystals are predominating. A new effect, just lately brought out, is a crocodile skin effect in white and blue, which was much admired by ceramists. This effect seems to have been produced by the application of a crystalline glaze over a light colored glaze.

The Faience Manufactory, Alumina, of Copenhagen, owned and operated by the management of the Royal Copenhagen, exhibited a full line of dinner sets painted in faience colors under the glaze. The effects were sharp and in great contrast to the Copenhagen designs.

P. Ipsens Enke, of Copenhagen, had a good exhibit of red earthenware figures, copies of the famous Danish artist Thorwaldsen, and of ancient Greek pottery. This firm also exhibited pottery in matt green, varied with a pleasing yellow matt.

H. A. Kaehler, of Naestved, exhibited lustre glazes, and his oxblood reds were of good quality. It was disappointing to note that his glazes were badly crazed. His matt glazes on stoneware were of a better technical finish. N. Hansen Jacobsen, of Copenhagen, had a small exhibit of masks, made of pottery, which did not find many admirers.

FRANCE. The pottery exhibits of France were divided into two parts; the Royal Sevres Manufactory and some amateur potters had exhibited in the French National Pavillion, while the French manufacturers were located in the Manufacturers' Building.

Of all the exhibits under this heading the Sevres National Manufactory was the best as far as location, surroundings and installation were concerned. In the Northwest wing of the National Pavillion we found two rooms devoted to these exhibits. In Sevres we have another well known old pottery. In 1740 Dubois started a pottery at Vincennes, which was the initial point of the Royal Porcelain Manufactory of France. This title was authorized in 1753 by King Louis XV, who at that time owned one-third interest in the business. In 1750 the pottery was moved to Sevres, and in 1760 the king became sole owner. After this period the state government has had more or less charge of its affairs, and it has been a government factory ever since. Sevres has produced some of the best porcelains made, and on its technical staff have served ceramists whose names are familiar the world over. The trademark of Sevres is an underglaze oval ring, with the letter S and the date of the year of manufacture. When the mark is cut through, it indicates that the piece was not decorated at Sevres. The productions of Sevres are identified more with the artistic than with the commercial side, and the result is that Sevres can produce pieces of pottery which would be prohibitive from the standpoint of a commercial concern.

In the French National pavillion was shown a rare collection of pottery, and while it cannot be said that there

was shown something distinctly new, it must be admitted that the technical art was more complete than at former expositions. One part of the exhibit consisted of large vases with flower and bird designs, which were good in shape and finish. In the middle of this group we found a large vase, about seven feet high, with a brown glaze in which there were unaccountable, large and small blue zinc crystals. This piece made a very good impression, and were it not for the defect of crazing, we could pronounce this vase excellent. In the technology of crystalline glazes Sevres is far advanced, and it puts aside the idea that crystalline glazes have no commercial value.

Here we found a large center piece for table use in which the design was in full harmony with the crystalline glaze application, also candle stick holders and other useful articles in which crystalline glazes produce effects which are strictly correct. In dinner sets we did not find many pieces, but the few plates exhibited were neatly designed and decorated. The art nouveau in soft porcelain had many excellent pieces, while in biscuit ware the busts of President Loubet and that of Lafayette were pieces of art. The pate-sur-pate decorations of Taxile Doat were very good. In stoneware, vases and figures were exhibited which were good in their class.

In the Manufacturers' Building we found Theodore Haviland and Charles Ahrenfeldt, both of Limoges. Of these two exhibits, Haviland gave us a very good idea as to what the pottery is capable of doing. Table ware decorated with the coats of arms of nearly all royalties of Europe were plain, but tasteful in design. The underglaze designs were good also. The firm had made efforts to produce crystalline zinc glazes and oxblood reds. The crystals on some pieces were good, while on others the crystal growth had been very small. The whole exhibit was attractive and well arranged.

Charles Ahrenfeldt also had several dinner sets made for royal use. A neat plain dinner set for the Queen of Holland deserved special mention. The decorations

were mostly over glaze with gold. The exhibit had a store-like appearance, but was well arranged.

Camille Naudet, of Paris, exhibited a line of porcelain which was excellent in design and color.

The possibilities of stoneware were shown by G. Hoentschel, of Paris. His exhibit was very instructive, and good effects were produced. This branch of pottery has not yet received much attention from the art potters in this country, and has far greater possibilities than faience for decorative design.

In the art palace and in another wing of the National pavillion, we found the exhibits of the ceramic amateurs of France. A. DeLacherche, Andre Mathey, F. Themar, A. Bigot and others exhibited some very good pieces of porcelain and stoneware, but there were also pieces which had no artistic nor technical character.

GERMANY. Of all pottery exhibits of this exposition, the display made by Germany was collectively and individually the best arranged of any country. Most of the exhibitors were concentrated in a hall or room, which was justly called "The Ceramic Court," located in the Varied Industries Building. The entrance to this court consisted of glazed terra cotta of Villeroy & Boch, of Mettlach, and the walls were partly covered with the colored and crystalline glazed tiles of Ludwig Wessel, of Bonn. In neatly decorated booths, scattered about in this space and along the walls, we found the representatives of the German ceramic industries.

A notable exception in this collective exhibition room was the Royal Berlin Porcelain Manufactory exhibit, which was located some distance away from this court. Its location was most unfavorable in regard to light and general surroundings, and it would have been a great deal better if it had been located closer to the Ceramic Court, or if it had been made a part of it in order to obtain a complete collection of all German potteries present.

The Royal Berlin Porcelain Manufactory, of Berlin, is royal not only in name but in fact. It is operated by

the Prussian Government, and it is therefore a state institution. The Royal Berlin, as the pottery is usually spoken of, was established by W. Wegely, in 1751, and became a royal factory in 1760, with the patronage of Frederick the Great. The pottery has had many ups and downs, but it has been the leading one for the last twenty-five years, and stands at the head of the technical application of modern ceramics. The trademark of Royal Berlin is a scepter, usually in under glaze blue, for plain glazed porcelain or an additional imperial globe with a cross with the letters K. P. M. in brown over glaze for decorated ware.

The present vigorous regime and the results accomplished are due to the director, Dr. H. Heinicke, who has associated with him Prof. H. Schley and Prof. Kips.

Studying the exhibit closely we found reproductions of several periods of the pottery's existence, true hard porcelain with over glaze decorations, big vases with cobalt blue ground on which flowers were harmoniously arranged. The enamel decorations were very good, and were applied with such skill that the technical part of this branch was nearly perfect. The new soft porcelain called "Heinicke Porcelain," in honor of its maker, Dr. Heinicke, was shown in many new forms and applications. It was used for crystalline glazes with very good zinc and titanic crystalline effects, for colored mottled glazes, for decorating between glaze layers, which technique has been made a special study by Dr. Heinicke. Schmuz-Baudiss used this body mostly for his productions. We found Seger porcelain in various forms and designs, and the little vases with oxblood red were excellent samples of the height to which this pottery has been raised.

Schmuz-Baudiss is the artist of the works. His productions were exhibited in a special case, and his work was excellent. He uses the body in the green, biscuit or glazed state. His specialty is under glaze design with the use of the aerograph, and his work must be considered a new departure of Royal Berlin with which they have made an excellent showing.

In the Mines and Metallurgy Building the manufactory had a most complete exhibit of chemical and technical porcelain, porcelain dishes over three feet in diameter, big developing trays about two feet square, distilling apparatus, pyrometer and other tubes and many other useful articles. In the Electricity Building the firm exhibited also some porcelain articles which are used in laboratory equipments. In the German state building we again found the Royal Berlin represented with large porcelain jardinieres, and big porcelain vases for decorative effects.

The Royal Bavarian Porcelain Manufactory, of Nymphenburg, had made a very good exhibit. This pottery is also royal, but has never been very prominent. During the last few years it has made great efforts to improve its output, and the exhibit showed what has been accomplished in that respect, and knowing the history of the plant we were astonished as to the results obtained.

A. W. Kister, of Scheibe, had a nicely arranged exhibit of porcelain figures and specialties, which were good in design and finish, while Hermann Ohme, of Niedersalzbrunn, exhibited porcelain dinner sets in different designs. Over glaze designs with rich gold decorations, and also blue glazed ware in gold decorated coffee sets, were good in technical execution.

Ph. Rosenthal & Co., of Selb, exhibited a full line of decorated porcelain mostly in under glaze designs. Some of the designs and colors approached closely the Copenhagen style, and might be considered good imitations. Here we also found a cobalt blue dinner set with gold decorations. Jaeger & Co., of Markt-Redwitz, had an exhibit which was very good in every respect. The color of this porcelain was excellent, and the designs were simple and tasteful. Special mention must be made of a fish set, in which a design of fishes in under glaze colors was very natural.

Heubach Bros., of Lichte, exhibited besides dinner sets in different designs and colors, also toys and other porcelain specialties. The exhibit was well arranged. Of

the china decorators Richard Klemm, of Dresden, represented the best skill. Arranged in a case we found several sets of plates decorated richly with portraits and scenes of Napoleonic times. The price marked on these plates was rather high.

In faience we found a large exhibit of Prof. Max Laeuger, of Karlsruhe. His work was of special interest. It showed the application of colored glazes to artistic production. Special mention needs the gold mosaic in glazes which produced fine effects. The large water fountain exhibited in the inner court showed that this firm is able to overcome great technical difficulties.

The Grossherzogliche Majolika Manufactur, and Prof. C. Kornhas, both of Karlsruhe, employ the same style of work and design. The first exhibitor made a specialty of lustre glazes, while Prof. Kornhas had tiles and pottery decorated with much gold. The body of the two first mentioned firms was for the greater part a red body, while Kornhas seems to prefer a stoneware body. His crystalline glaze effects on stoneware were very promising.

Reinhold Hanke, of Hoehr, represents the German stoneware manufacturers. His productions deserved much attention, his colored and oxblood red glazes were good, and his collection of steins was excellent.

J. J. Scharvogel, of Munich, exhibited also faience and stoneware of good design, and rich in effect. Among the other exhibitors we find Hermann Mutz, of Altona, Schmidt-Pech, of Konstanz, W. Magnussen, of Bremen, who had mostly exhibited a few pieces of art pottery.

Great Britain. In sharp contrast to the impressions gained of France and Germany in regard to their pottery exhibits, we found Great Britain's collective pottery industry exhibited in plain black show cases, with no attractions whatever, in the Varied Industries Building. In order to study the exhibits closer we were compelled to seek the man in charge who, however, was unable to give any data relative to the work, except that he had a numbered price list and was eager to sell the goods under his jurisdiction.

One of the two firms who had made a special exhibit was Doulton & Co., of London. The exhibit itself was harmonious and well arranged. This firm manufactures nearly everything that can be made from clay. It manufactures drain tile, sewer pipe, fire clay goods, stoneware, chemical goods, bone china and artware. The works were founded by John Doulton in 1818, and have been in successful operation by the same family ever since. The name "Royal Doulton" was granted recently by special act of King Edward VII. Salt glazed art ware, which has for years made the name of Doulton known over the world, was found in many shapes and designs. Lambeth faience was well represented, and some of the pieces exhibited were excellent. In bone china with modern designs we found many vases and plates which are good examples. In red copper glaze pottery we found many good pieces, but it seems a pity that such a well known firm should try to deceive the buying public, by publishing in a pamphlet the statement that they have discovered a long lost art. These red glazes, which are obtained by reducing copper at a low heat, have been made by Roseville and Zsolnay for years, with good results. The art was certainly not lost nor rediscovered, and while the pieces exhibited were good, of an oxblood red glaze on true hard porcelain, we were unable to discover even a trace. In the Art Palace we found a few samples by the same firm, and in the Liberal Arts Building there was an excellent exhibit of chemical stoneware, of which a large distillation worm attracted special attention.

The other firm exhibiting outside of the collective exhibit was that of Sir Edmund Harry Elton, Baronet, of Somerset. The product is called "Elton Ware," and is made in the Sunflower pottery at Somerset. Sir Elton designs all his pottery personally, and his artistic talent is of a high order. The clay body was red, and some of his colored glazes were badly crazed. His golden crackle was very effective, and his lustre colors were good.

In the collective exhibit of the potteries we find Minton's Ltd., of Stoke-upon-Trent, with pate-sur-pate paint-

ings by Solon. These productions were excellent, and the values were in harmony with the same. A vase with "Nymphes catching Cupid" was valued at $3,750, while another vase with owls, which was very good in design, was marked at $4,200. A few excellent, decorated plates were shown as samples of the general work of the pottery. W. Howson Taylor, of Birmingham, exhibited his Ruskinware with flowing blue and green glazes, in vases and specialties, while James McIntyre & Co., Ltd., of Burslem, exhibited art pottery in original designs, which made a good impression. Other art potters who made exhibits were Wardle & Co., Ltd., of Hanley, and W. L. Baron, of Barnstaple. G. L. Ashworth & Bros., of Hanley, exhibited a full line of their original Mason Ironstone China. The Crown Staffordshire Porcelain Co., of Staffordshire, Johnson Brothers, Ltd., of Hanley, Alfred Maekin, Ltd. and Booths, Ltd., both of Tunstall, exhibited dinner sets and plates in decorated designs with gold, mostly in over glaze, while John Maddock & Sons, Ltd., of Burslem, showed good samples of under glaze designs.

HUNGARY. In the Manufacturers' Building Hungary had a well arranged collective exhibit of national architecture, in which we found the pottery exhibits. Miklos Zsolnay, of Budapest, exhibited the products of the pottery of Wilhelm Zsolnay, of Fuenfkirchen, (Pecs). The Zsolnay pottery has a well known reputation, and the exhibit was excellent in quality. We found a large assortment of its "Eosin" red lustre ware, which was very creditable, also majolica and ivory porcelain art-ware. Jeno Fischer, of Herend, exhibited a nice line of decorated dinner sets, while Emil Fischer, of Budapest, showed a fine line of porcelain dinner sets and majolica vases. The Hungarian Trading Co., Ltd., of Budapest, exhibited a variety of different kinds of pottery, of which the stoneware pieces of Hollohaza were excellent.

INDIA. In the East India Pavillion we found a collection of pottery, which was partly majolica and whiteware, exhibited by Ardeshire & Co., of Bombay.

IRELAND. While not officially exhibiting as a country, we found in the Irish Village, on the Pike, the exhibits of the Irish Industries. We found in the pottery line the Belleek Pottery Works, of Belleek, the Fermanach Co. This firm exhibited open work pottery in a very white color. Vases were decorated with flowers and under relief designs. Lustre colors applied produced excellent pearl effects. Another Irish firm was the Della Robbia Co., of Birkenhead, Cork Co., which exhibited majolica ware of good quality.

ITALY. Typical Italian faience and majolica were well represented in the Manufacturers' and Varied Industries Buildings. Bernardino Mazzarella, of Naples, made one of the best exhibits in that line with large vases, richly modeled in relief with flowers and decorated in majolica colors. Edoardo D'Amato, also of Naples, exhibited a line of fancy pottery, which was good. The Manifattura di Fontebuoni and of di Signa, both of Florence, exhibited large jardinieres and specialties which were pretty good. All the ceramic exhibits were, however, badly entangled among furniture, silver and other exhibits, and it was difficult to obtain a good idea as to the extent of the Italian pottery. In the Art Palace we found, besides Fontebuoni with some excellent pieces, G. Gregori, with a good majolica exhibit.

JAPAN. Of all countries, in regard to the largest numbers of pottery exhibits, Japan was the leading one. The catalogue gives 86 porcelain and 89 stoneware and earthenware exhibitors. Most of the pottery was exhibited more with a view to selling than of exhibiting its quality. The best exhibits were in the Art Palace, while the balance were located in the Varied Industries Building. Typical Japanese porcelain we found exhibited by Sobie Kinkozan, of Kyoto, who had a very good exhibit. The porcelain exhibited by Meizan Yabu, of Osaka, was of good design and shape. Both exhibited also in the Art Palace. T. Hodata, of Yokohama, showed some excellent pieces of porcelain. One of the most complete exhibits was made by Koranshi & Co., of Kyoto. Here we found Arita porce-

lain, Arita-Hizen art ware and Imari pottery in large quantities and of good quality.

The earthenware and stoneware exhibits were really of a higher character than the porcelain branch. K. Miyagawa, of Yokohama, exhibited very good ware, while Takito & Co., of Nagoya, presented their results in crystalline glaze effects. T. Kota, of Tokio, and G. Koran, of Saga-Ken, exhibited stoneware of good quality and rich in design. In the Art Palace we found beside some of the exhibitors already mentioned, the Kyoto Pottery & Porcelain Co., of Kyoto, who exhibited yellow mottled matt glazes, and J. Uno, also of Kyoto, with green matt glazes. We observe that the Japanese adopt European designs and shapes more and more, and that the characteristics of typical Japanese ware are disappearing. Before long Japan will be a serious competitor on our home market.

MEXICO. The Junta Local de Exposicion, of Puebla, exhibited white ware and faience pottery in the Manufactures Building. Some of the dinner sets were decorated in blue under the glaze, and some showed over glaze decoration. With additional technical improvement this firm ought to be able to make first class ware for the home market. E. Chateaumorand, also of Pueblo, exhibited a few pieces of pottery, of a porcelain like character.

NETHERLANDS. Among the pottery exhibits of the Netherlands in the Varied Industries Building, are two well known firms. The old Delft faience pottery of Joost, Thooft & Labouchere, called "De Porceleyne Fles," of Delft, is the older one of the two. This pottery was established in 1655, and has been in operation under different managements ever since. Its trademark is the outline of a jar, with the name Delft always in blue under the glaze. The exhibit of this firm formed an interesting collection. Here we found first of all, reproductions of the old Pynacker faience, which was made in 1660 after the pottery was first started. Next comes old Delft faience of a red body and stanniferous glaze, with blue over glaze decorations. Productions of a later period are dark gray bodies with tin glazes. Then we come to the modern Delft

ware of a bluish white body, with transparent glaze and blue under glaze decoration. The tile exhibit of this firm was described under part IV. On a separate table was exhibited a large collection of the results of modern glaze technology. Here we found vases with beautiful crystalline glaze effects, lustre colors, matt glazes and other productions. This exhibit showed that this pottery, while preserving its traditional name as "Delft," is able at any time to share with its competitors the results of modern ceramics.

The Royal Porcelain and Pottery Manufactory "Rozenburg," of the Hague, is the other firm. This pottery exists since 1883, and was granted the privilege of calling itself "Royal" by the Queen of Holland in 1901. The trademark of Royal Rozenburg is the city seal of the Hague—a stork on one leg—with a crown, and the name "Den Haag." This trademark is somewhat confusing, in as much as the old porcelain factory which existed from 1778-1795, and whose products bring high prices today, had the same mark, without the crown.

The main feature of Royal Rozenburg was its bone china, artistically decorated in original style. The lightness of this porcelain was commended upon by every one. The body was very white and translucent, and gave evidence that the technical problems were well taken care of. The exhibit further showed the old Dutch faience work, which was the original beginning of the pottery. Wed. N. S. A. Brandjes & Co., of Purmerend, exhibited a full line of artistic faience pottery, while the Plateelbakery "De Distel," of Amsterdam, and the Plateelbakkery "Delft," of Hilversum, showed pottery of no special original design.

PERSIA. In the Persian pavillion we found a case with old Persian pottery exhibited by D. Kelekian, of Dikran Khan, which included some excellent pieces in turquoise and Persian blues.

PORTUGAL. In the Manufactures' Building, the Fabrica de Faiancas das Caldas da Rainha, of Caldas, showed a line of Portuguese majolica and faience which were characteristic of that country.

SIAM. The Royal Commission exhibited in the Manufactures Building earthenware, which was made by the natives, while the Udawn Committee showed samples of the same class of pottery decorated in various colors.

SWEDEN. This country had made quite an interesting exhibit of pottery in the Manufactures Building, and the leading manufacturers were well represented. The Rorstrand Porslinfabrik, of Stockholm, exhibited a line of decorated porcelain of the style of the Copenhagen, but heavier in body. The application of crystalline glazes was brought to commercial perfection, and the articles exhibited were a credit to the firm. Majolica vases and table ware were good in design and color.

The Gustafsberg Pottery Co., also of Stockholm, exhibited whiteware in table and toilet sets, as well as vases in majolica, which were neat and plain in design. The parian biscuit for statuary was very pleasing, and showed some good modeling.

UNITED STATES. The pottery exhibits of the United States were well distributed all over the World's Fair grounds, as already mentioned before. A few of the main exhibits of the leading art potteries were located in the Varied Industries Building, while nearly all other exhibits, with few exceptions, were located in the Mines and Metallurgy Building.

ARIZONA. Indian pottery was exhibited by J. W. Benhem, of Phoenix, in a well arranged exhibit in the Anthropology Building.

ARKANSAS. The Eagle Pottery, of Benton, exhibited in the Mines Building some very good stoneware in white and brown glazes.

COLORADO. The Van Briggle Pottery, of Colorado Springs, exhibited at three places, the Art Palace, the Mines, and the Varied Industries Buildings. The main exhibit was located in the latter. The products of this pottery were blended matt glazes on a close, nearly vitrified, stone ware body. The forms and designs of vases and other specialties were plain, with occasional decoration in

light relief. The matt glazes produced imposing effects, and the blending of the same is artistic. The colors, which were quite numerous, vary from gray, green, red, yellow and blue to blue green.

CONNECTICUT. The Hartford Faience Co., of Hartford, exhibited in a large case electrical porcelain in all shapes and forms. This exhibit was part of its main exhibit in the Mines Building.

ILLINOIS. The art pottery of the state is the Gates Potteries, of Chicago. The works are located at Terra Cotta, and the product, "Teco" ware, is manufactured there. The exhibit was located in the Varied Industries Building, in a neatly designed booth. The forms of Teco are original, they are mostly designed by artists. The green matt glaze is characteristic of Teco. It does not possess the harsh feeling which some matt glazes show, and has a soft surface. Porcelain vases with effective crystalline glazes, and faience, with gold spangled effects were represented by samples, showing that the technical problems are well mastered by the firm. Special pieces were also exhibited in the Art Palace.

In the Mines building the Weir Pottery Co., of Monmouth, exhibited a full line of its fruit jars of stoneware in a patent design. The Shelton Pottery, of Metropolis, presented stoneware products.

INDIANA. In the Varied Industries Building we found a neatly arranged exhibit of the State Association of China Decorators, of Indianapolis. Of the 35 exhibitors catalogued under group 45, Ceramics, 24 belong to this one collective exhibit.

IOWA. The Fort Dodge Stoneware Co., of Fort Dodge, exhibited with the Iowa Commission in the Manufacturers' Building a full line of its white glazed stoneware, jars and crocks, while in the Mines Building, both the Red Oak Pottery Co., of Red Oak, and the Fort Dodge Pottery Co., of Fort Dodge, exhibited their stoneware products.

LOUISIANA. The Newcomb Pottery, of New Or-

leans, had its main exhibit in the Mines Building, while a few pieces found a place in the Art Palace. Newcomb Pottery had its origin in the Art Department of Newcomb College, of New Orleans, and is made by women under the supervision of the college. The subjects of the designs were flower reliefs, and also glaze effects.

KANSAS. The Fort Scott Pottery Co., of Fort Scott, exhibited stoneware in different shapes, mostly in brown glazes, in the State exhibit in the Mines Building.

MARYLAND. A large case with pottery exhibited by the Baltimore potteries, was located in the Mines Building. The Edwin Bennett Pottery Co.,, and D. F. Haynes & Son, both of Baltimore, exhibited table ware and toilet sets, richly decorated, jardinieres and specialties. The exhibit was well arranged, and showed a large variety of products. Other pottery exhibitors were George S. Kalb & Son, of Catonsville, and M. Perine & Son, of Baltimore, with stoneware and earthenware articles.

MASSACHUSETTS. The Grueby Faience Co., of Boston, exhibited, as already mentioned under part IV, in the Varied Industries Building. Some pieces of pottery were also on exhibition in the Art Palace. The Grueby Faience Co. had a neatly designed exhibit, in which architectural terra cotta was predominent. In pottery we found a line of lamp bases, which formed the attraction of the exhibit. The pottery was finished in a matt green glaze of light shade. Some pieces have also a blue matt finish.

In the Art Palace H. C. Robertson, of Dedham, exhibited flowing colored glazes, lustre effects which were good, while the Merimac Pottery, of Newburyport, showed a collection of vases in different designs and colors.

MISSISSIPPI. The greater part of the state exhibit in the Mines building was devoted to the products of the clay artist, George E. Ohr, of Biloxi, articles in nearly all imaginable forms and designs. They were finished mostly in bright colored glazes, though some lustre and matt effects were found on several pieces.

NEW JERSEY. The Trenton Potteries Co., of

Trenton, made a splendid exhibit of its sanitary products in the Manufactures Building. Glazed white wall tiles, white porcelain wash-stands, bath tubs, in fact, even the door knobs and the plumbing were executed in white porcelain, thus illustrating a bath room, completely finished in white. Another bath room was in the same style but finished with gold decoration. In order to illustrate the work of the firm along other lines, a few cases with splendidly decorated pottery, consisting of vases and specialties in over glaze work, were also exhibited.

The Fulper Pottery Co., of Flemington, exhibited a line of stoneware filters in blue Flemish design, in the Mines building, while in the Art Palace we found a few samples of the Poillion Pottery Co., of Woodridge.

None of the Trenton or New Jersey general whiteware potteries had made an exhibit. They were not even represented in the State exhibit with a collective exhibit, and in that respect they showed still less intelligence than their competitors in other states. Such a pitiful state of affairs among our American potters is evidence of the total lack of self respect and confidence towards their own products.

New York. The Onondaga Pottery Co., of Syracuse, made a very interesting exhibit of its bone china products in the Clay Industries Exhibit in the Mines Building. It made a very creditable showing, and may be considered the best exhibit made in the United States for table ware. The designs and decorations were conventional in style, and were in strict harmony with the ware. The color of the body was excellent, and the glaze was perfect. It was an instructive exhibit for the foreigners, which showed them that America will, in the future, be capable of competing with Europe in that branch of ceramics.

In the same section the Brouwer Pottery, of Westhampton, had made an exhibit. Mr. T. A. Brouwer himself is the designer and potter. His ware comprises lustre effects, and his gold leaf work, under the glaze, deserved special mention.

Charles Volkmar, of New York, exhibited in the Art Palace samples of his art pottery. Electrical porcelain was exhibited in the Mines building by the Empire China Works, of Brooklyn, and in the Electricity building by the Locke Insulator Mfg. Co., of Victor.

OHIO. The Rookwood Pottery Co., of Cincinnati, had its main exhibit in the Varied Industries Building. This exhibit embraced products of all periods, and included the latest achievements in design and finish. We found original "Rookwood" with the glaze slip decorated ware in yellow and dark colors, the lighter shades of "Sea Green" and "Iris" ware, gold stone and tiger eye samples of crystalline glazes, and finally the matt glazes in green and other colors. The latest product was the "Vellum" ware in transparent matt glaze, with light decorations. In finish, texture, and application, this glaze must be considered the best product this pottery has ever turned out. By its application the artist is given full credit for his design, and the dull transparent finish reproduces the full effect of the painting. Rookwood exhibited also in the Art Palace, in the Clay Industries Exhibit in the Mines Building, and in the Anthropology Building, where Rookwood pottery illustrated the application to modern art of the forms and decorative motives derived from the fictile art of the North American Indians.

The Roseville Pottery Co., of Zanesville, exhibited in the Clay Industries Exhibit in the Mines Building, a full line of its various styles of pottery, and the productions represented an excellent quality. "Rozane" ware, which has a copper red, reduced, glaze gives good effects, and while the technical part was not quite perfect on some pieces, the ware has a bright future as being in the same class as Zsolnay's Eosin ware and Doulton's "Lost Art" ware.

The Weller Pottery Co., also of Zanesville, which we have already mentioned under the educational part, had exhibited a full line of its products, in their main working exhibit in the Mining Gulch. In the Clay Industries Exhibit in the Mines Building they also had a good exhibit. Of the different styles exhibited we found the Aurelian ware,

Louwelsa ware, Eocean ware and Sicardo Lustre ware to be the best. Beside this full line of art ware, they also showed a full line of cooking ware, which indicates the many varieties which the firm is able to manufacture.

The Owens China Co., of Minerva, was the only individual exhibitor of American whiteware in the Varied Industries Building. The exhibit showed some good samples of table ware in semi-porcelain, the decoration being a good quality.

In the Ohio State exhibit in the Clay Industries Exhibit in the Mines building, we found samples of fourteen whiteware potteries of East Liverpool, which consisted of only one plate of each pottery, while samples of plates of other potteries outside of East Liverpool were also exhibited. The Edwin M. Knowles China Co., of East Liverpool, and the Pope Gosser China Co., of Coshocton, had made a somewhat better display in exhibiting more pieces. The McNicoll Pottery, of East Liverpool, showed yellow ware. Stoneware as jars, crocks and cooking ware was represented by the Zanesville Stoneware Co., the Zanesville Filter & Pottery Co., both of Zanesville, the Logan Pottery Co., of Logan, and the Robinson Clay Products Co., of Akron.

Art Pottery was represented in this state exhibit by the Oakwood Pottery Co., of Dayton, the Florentine Pottery Co., of Chillicothe, the Arc-Enciel Pottery Co. and the Zanesville Art Pottery Co., both of Zanesville. These exhibits were for the greater part lustre productions, with the exception of the Dayton firm, which had a green matt glaze.

In electrical specialties we found the exhibits of the Akron Insulator & Marble Co., of Akron, F. W. Brunt Pottery Co., of East Liverpool, and the New Lexington High Voltage Porcelain Co., of New Lexington.

PENNSYLVANIA. Beside the Mayer pottery exhibit of Beaver Falls, already mentioned before, we found in the Clay Industries Exhibit in the Mines Building the Sherwood Bros. Pottery Co., of New Brigton, with a full line of its stoneware specialties.

TEXAS. Several small pottery concerns of the state exhibited in the Mines Building stoneware products, which were of good quality.

WISCONSIN. Sampson & Ipson, of Edgerton, exhibited in the Mines building samples of their Norse ware. While it can not directly be classified as strictly ceramic ware, it being a red body painted with oil colors and finished in ancient Greek style, it must be said that the product had some merit.

The Pauline Pottery Co., also of Edgerton, exhibited in the Wisconsin State Building some very good specimens of under glazed faience.

Resume on Part VI.

A review of the exhibits described under this heading reveals a most interesting study. We have seen the exhibits of pottery of all the leading countries of the world, and what do we find? Every country has its own designs and decorations, and its own distinctive pottery. We further found that in every country the leading class of pottery is imitated by others in the same country, sometimes very closely, and sometimes with variations, but nevertheless, they are imitations.

Taking the leading exhibits of each country, we found in Germany that over and under glaze decorated porcelains are most in vogue. In France, artistic stoneware and crystalline glazes are favorites. In Denmark and Sweden, the two northern countries, under glaze porcelain is cultivated with art and skill. In Japan the old Japanese style still holds its own, with a few European imitations. Holland has its own Delft blue, while Italy is still the home of old majolica. In Austria a gray porcelain matt is much admired, while in our own country a green faience of velvet finish is a propitious article.

The progress made by Royal Berlin in porcelain and by Royal Doulton in stoneware, for technical, chemical and electrical purposes, is great, and before long we will find porcelain and stoneware substituted in many processes where formerly metal appliances were used.

Coming to the United States we have observed with pain the total absence of American whiteware potteries as individual exhibitors, with the exception of one small exhibit. This absence may be construed as having two explanations. First, that the whiteware potters were afraid to go before the world with their goods in competition with foreigners, and thus silently admit their inferiority, or secondly, that they were so narrow minded as to fail to see the benefit to be derived from open advertising and public exhibition. In porcelain we do not have anything to show, while in bone china the Onondaga Pottery Co., of Syracuse, N. Y., produces ware of excellent quality.

We look to expositions, as a rule, for new productions and exhibits of new processes, and we naturally ask ourselves what new features were observed in the pottery lines, from an international standpoint. The answer is that there is nothing new with the exception of the Vellum ware of the Rookwood Pottery Co., of Cincinnati. The fine exhibits of Germany, France, Denmark, Sweden and Holland, especially along the crystalline glaze line, were a treat to many of us, who were permitted to look upon these productions for the first time, but the Paris Exposition of 1900 showed us exactly the same thing. It may be possible that the technology of the successful commercial production of these effects has been more complete than before. The pieces exhibited do not give us, however, any information in that respect.

PART VII. CONCLUSIONS.

In the preceding chapters we have endeavored to review the exhibits of the ceramic industries. We have given a resume in each section in order to make the same more complete, and we will now conclude this review with a few suggestions and conclusions.

Summing up all the exhibits, the Louisiana Purchase Exposition goes down in history as having been a good and fair exhibition of the Ceramic Industries. We could have expected more exhibitors and more detail in the exhibits proper, however, in most cases the best firms had

made exhibits, and the products exhibited were a fair average of each country.

From an American standpoint we still have much to learn from our older competitors, in order to raise our home production to such a standard that importation may be diminished. This is especially the case in table ware products, where it is only a matter of technical perfection in order to produce pottery as good as that made abroad.

In chemical stoneware, we could at least try to manufacture such ware. Our stoneware clays are well adapted for it. Our mechanical and technical skill is such that it will overcome any difficulty pertaining to its manufacture.

In the porcelain line, the chemical and technical sides are still lacking commercial support in order to manufacture such goods in this country.

Judging from a foreign standpoint, we Americans have shown that we are an enterprising, investigating and rapidly learning people, and that they must be on their guard in order to retain the trade already established.

Opinions expressed by visiting members of the foreign ceramic industries, personally, and in the foreign trade literature, praise the American displays made by the coarser grades of the ceramic art, while they express a feeling of disappointment in the exhibits of finer ceramics, with the exception of the art ware line. From these same sources we learn that our Society is held in high esteem abroad, and that they fully realize the good work which has been done by our members so far, which tends to produce better quality rather than greater quantity.

As all exhibits have surprising or disappointing features, it must be noted that the impossibility of collecting data in regard to the exhibits proper, and the difficulties encountered in this work were most disappointing. In those exhibits which distributed pamphlets or circulars we were able to obtain a better idea of the pieces exhibited than in those in which such matter was entirely lacking. If we inspect and study an exhibit from the commercial or technical standpoint, we want to know some facts in order

to familiarize ourselves with the product presented. The lack of such facts lessens the interest, and the exhibit, may it be as good as could be produced, is passed by as incomplete. We found the foreigners in better shape in connection with such matters than the Americans. The Clay Industries Exhibit in the Mines Building was, with few exceptions, entirely lacking in this respect. It would, therefore, be advisable to impress upon future exhibitors the importance of this feature as being not only good advertising, but also conductive to public education.

Another bad feature of the exposition was that the commercial side was given too much prominence. Exhibits were more arranged on the style of a bazaar or bargain counter than in the spirit of an exposition, purely and simply competitive in design, quality, workmanship and finish.

Before closing this chapter there are two points of a general nature upon which we will touch. Inasmuch as we personally do not consider that sand-lime bricks have any more right to be collected under the head of "Clay Industry" than glass or cement, we did not consider in this review the sand-lime brick exhibits in the Clay Industries section, as they were out of place in that otherwise well arranged collective exhibit of the American Ceramic Industries.

As expositions are likely to be held again, and juries of awards are sure to be made again part of such expositions, we make a strong plea for a better understanding of the duties and qualifications of the jury which is to judge the ceramic industry. At this exposition we found two international juries judging this industry, one composed of technical men, on which members of our Society were well represented, and another composed, with a few exceptions, of commercial men and art lovers. The first named jury judged everything in the Mines Building from clay to finished products, while the other jury only judged finished products as exhibited in the Manufacturers' and Varied Industries Buildings. This division made a very

bad impression upon the exhibitors and foreign jurors. The leading foreign countries like Germany, France and Japan had experts appointed for jury duties, and these jurors were, for the greater part, unable to exercise their full duties in regard to judging the whole industry, on account of this division.

The Ceramic Industries of the world have long since grown out of their childhood, and should be able to see to it that the judging of its products, be it in an international or a national contest, should be done by experts, who are able to determine and judge the value of a clay sample or the highest class product made from the same, in order to give weight and value to exposition awards.

A COMPARATIVE STUDY OF CORNWALL STONE AND FELDSPAR IN RAW LEAD GLAZES.

BY

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Among many glaze makers of America there is a decided preference in favor of the use of English Cornwall stone over that of American feldspar as a glaze ingredient. This is a preference that is exhibited not only by the potters of English training, but also by men who have a technical ceramic education, and whose practical experience has been gained entirely in America.

Some of the most definite reasons given for their preference of stone by those who use it are,

(1) That it works well in the dipping tub.

(2) That it matures earlier.

(3) That the glaze is less liable to craze, owing to its earlier maturity, hence becoming more uniform and less liable to strain.

Conclusions reached by gathering opinions alone, even when only practical men of long experience are consulted, are always subject to a heavy discount, because practical men and technical men are seldom able in the rush of daily business to fully investigate both sides of a question, and their opinions are thus seldom the result of a deliberate balancing of all variable factors in the case.

The following experiments were undertaken to see whether any material difference could be recognized between two glazes having the same chemical formula, using feldspar in one and Cornwall stone in the other.

The spar used was what is known as Brandywine feldspar, obtained from the Brandywine Summit Feldspar & Kaolin Company. On analysis it was found to have the following composition:

SiO_2	65.78	Per cent.
Al_2O_3	19.12	

K_2O	11.91	Per cent.
Na_2O	1.82	
CaO	0.41	
MgO	0.12	
Volatile	0.80	
	99.96	

On calculation, the molecular formula was found to be as follows:

$$\left.\begin{array}{l} 0.7632\ K_2O \\ 0.1747\ Na_2O \\ 0.0439\ CaO \\ 0.0181\ MgO \end{array}\right\} 1.1264\ Al_2O_3 \quad 6.6023\ SiO_2 \quad .2648\ H_2O.$$

Combining weight 601.54.

The Cornwall stone was obtained in the ground condition through Messrs. Golding & Sons Company, and had the following composition:

SiO_2	72.21	Per cent.
Al_2O_3	16.32	
K_2O	4.39	
Na_2O	2.86	
CaO	2.02	
MgO	0.20	
Volatile matter	1.97	
	99.97	

Molecular Formula:

$$\left.\begin{array}{l} 0.3490\ K_2O \\ 0.3445\ Na_2O \\ 0.2691\ CaO \\ 0.0374\ MgO \end{array}\right\} 1.1958\ Al_2O_3 \quad 8.995\ SiO_2 \quad .8221\ H_2O.$$

Combining Weight 745.2.

The average analysis of 12 other samples of Cornwall stone was found to be:

SiO_2	72.43	Per cent.
Al_2O_3	17.13	
Fe_2O_3	0.36	
$KNaO$	6.10	

CaO	2.25	Per cent.
MgO	0.27	
Volatile	1.76	
	100.30	

Average Molecular Formula:

$$\left.\begin{array}{l}0.6281\ KNaO\\0.3223\ CaO\\0.0490\ MgO\end{array}\right\}\left.\begin{array}{l}1.3497\ Al_2O_3\\\\0.0181\ Fe_2O_3\end{array}\right\}10.1227\ SiO_2\quad .7853\ H_2O.$$

On comparing the sample used in this experiment with the above, it is seen that it is richer in fluxing elements than the average stone. For this reason any difference between feldspar and Cornwall stone noted in the following experiments might have been more marked, if the stone used had approached nearer to an average sample.

In grinding, blending, dipping, setting and burning, the glazes of the different series of feldspar and Cornwall stone received the same treatment throughout. The extreme members of each series of glazes were ground in small porcelain lined ball mills, using porcelain balls to do the grinding. The glazes were ground for one and one-fourth hour into a slip that contained 60% of distilled water, and blends were made between these extremes for the intermediate glazes. The glazes were applied on standard white tiles, 1½x3x½ inches, made by the Beaver Falls Art Tile Company. The tiles were set on fire clay plates, or "setters," in saggers that were large enough to hold two whole series, side by side. The saggers were set near the center of a down draft test kiln, whose kiln chamber was 5′9″ high, 2′7″ long and 22″ wide. The space not occupied by saggers was filled with fire brick, in order to obtain a more uniform draft.

Each glaze was fired at four different temperatures, cones 05, 02, 5 and 9, taking two hours to get the last cone down. The cone 05 and 02 burns were each made in 16 hours, the cone 5 burn in 24 hours, and the cone 9 burn in 33 hours. This burn was not as satisfactory as the first three had been. The cones outside the sagger all went down

in nice regular order, and on examining them when the kiln was drawn, none of them showed signs of bloating, but all of them were either glasses, or in the case of the highest cones, were well vitrified masses. On opening the saggers, cone 8, the only cone placed there, was found to have entirely lost its shape and had become a vesicular mass.

During the first part of the last burn, owing to the fuel running short, it was necessary to hold the temperature of the kiln between 800° and cone 010 for 10 hours, using a bituminous coal for a large proportion of the fuel fired. During this period the cone was probably attacked by sulphurous gases, and when the heat was raised they caused the cone to bloat. Whatever it was that caused the cone to bloat would be equally likely to affect the glazes that were in the same sagger with the cone in the same manner. So it would be expected than any over-firing defects that these glazes showed at cone 9 would be exaggerated, owing to the bad condition of the gases in the sagger.

In the following table will be given the glazes made; ingredients used, whether feldspar or Cornwall stone, their oxygen ratio, RO content, equivalents of alumina and silica, and the four temperatures at which they were burnt.

In describing the condition of the fired glazes, at all temperatures used, *bad* indicates a glaze that has some serious defects, it is immature, fails to flow or is overburnt; *good* indicates one that shows no defects; the numerals below the word good are the range of Al_2O_3 content in which good glazes were obtained.

TABULATED RESULTS OF THE COMPARATIVE FELDSPAR AND CORNWALL STONE GLAZE SERIES.

Series Number	Oxygen Ratio	Range of Al_2O_3	RO	FELDSPAR				CORNWALL STONE			
				Cone 05	02	5	9	05	02	5	9
I and II	1:1.75	0.1724—0.5	0.100 KNaO 0.094 CaO	bad	bad	bad	good 0.1724—0.25	bad	good 0.1724—0.30	good 0.1724—0.30	bad
III and IV	1:2.00	0.1724—0.5	0.006 MgO 0.100 ZnO	bad	bad	good 0.1724—0.35	bad	bad	good 0.1724—0.25	good 0.1724—0.35	bad
V and VI	1:2.50	0.1724—0.5	0.700 PbO	bad	bad	good 0.1724—0.25	bad	bad	bad	good 0.1724—0.25	bad
VII and VIII	1:2.20	0.2586—0.5	0.150 KNaO 0.141 CaO	bad	bad	good 0.258—0.4	bad	bad	bad	good 0.2258—0.45	bad
IX and X	1:2 50	0.2586—0.5	0.009 MgO 0.150 ZnO	bad	bad	bad	bad	bad	bad	good 0.2258—0.30	bad
XI and XII	1:3.00	0.2586—0.5	0.550 PbO	bad	bad	bad	bad	bad	bad	bad	bad
XIII and XIV	1:2.55	0.3448—0.75	0.200 KNaO 0.189 CaO	bad	bad	bad	bad	bad	bad	bad	bad
XV and XVI	1:3.00	0.3448—0.75	0.011 MgO 0.150 ZnO	bad	bad	bad	bad	bad	bad	bad	bad
XVII and XVIII	1:3.50	0.3448—0.75	0 450 PbO	bad	bad	bad	bad	bad	bad	good 0.3448—0.45	bad
XIX and XX	1:2.55	0.3448—0.75	0 200 KNaO 0.078 CaO	bad	bad	bad	bad	bad	bad	good 0.3448	bad
XXI and XXII	1:3 00	0.3448 - 0.75	0.011 MgO 0.711 PbO	bad	bad	bad	bad	bad	bad	bad	bad
XXIII and XXIV	1:3.50	0.3448—0.75		bad	bad	bad	bad	bad	bad	bad	bad
XXV and XXVI	1:2.00	0.0862 - 0.5	0.050 KNaO 0.147 CaO 0.003 MgO 0.100 ZnO 0.700 PbO	good 0.0862—0.2	good 0.0862—0.35			good 0.0862—0.35	good 0.0862—0.40		

COMPARISON OF LIKE SERIES.

Series I and II.

On comparing series I, feldspar, and series II, Cornwall stone, at cone 05, series II is a little more fusible than series I. At cone 02 series II is again a little more fusible than series I, and the glazes cover better, there being three good glazes, Nos. 9, 10 and 11 with Cornwall stone, and none with feldspar. At cones 5 and 9 there is no difference.

Series III and IV.

On comparing series III, feldspar, and series IV, Cornwall stone, it is seen that at cone 05 series IV is a little more fusible than series III. At cone 02 the same holds true, there being two good glazes, Nos. 25 and 26, with Cornwall stone, and none with feldspar. At cone 5 they are about equal, series III having four good glazes, Nos. 17-20, and one fair, No. 21. Series IV has three good glazes, Nos. 25-27, and two fair, Nos. 28 and 29.

Series V and VI.

On comparing series V, feldspar, and series VI, Cornwall stone, at cone 05, series VI is a little more fusible than series V. At cone 02 the difference is a little more marked. At cone V, series VI has a little the better of it, there being two good Nos., 33 and 34, with feldspar, as against two good Nos., 41 and 42, and three fair ones, Nos. 43, 44 and 45, with Cornwall stone. At cone 9 there is no difference.

Series VII and VIII.

On comparing series VII, feldspar, and series VIII, Cornwall stone, at cone 05, series VIII is a little more fusible than series VII. At cone 02 the same difference holds. At cone 5 they are about equal, there being three good Nos., 49, 50 and 51, and one fair one, No. 52, with feldspar, as against three good Nos., 55-57, and two fair Nos., 58 and 59. At cone 9 there is no difference.

Series IX and X.

On comparing series IX, feldspar, and series X, Cornwall stone, at cone 05, series X is a little more fusible than series IX. At cone 02 the same difference holds as to fusibility, but the glazes of series X lie flatter than those of series IX. At cone 5 there are no good glazes in series IX and one in series X, No. 68. At cone 9 there is no difference.

Series XI and XII.

On comparing series XI, feldspar, and series XII, Cornwall stone, at cone 05 the different members of series XII are more fusible and lie much flatter than those of series XI. At cone 02 the same difference holds. At cone 5 series XII has a little less undissolved material in the glazes. At cone 9 series XII covers the tile better than series XI.

Series XIII and XIV.

On comparing series XIII, feldspar, and series XIV, Cornwall stone, series XIV is more fusible, and the glazes lie flatter for every temperature than in series XIII. Series XIV has one fair glaze, while series XIII has none that could be classed as such.

Series XV and XVI.

On comparing series XV, feldspar, and series XVI, Cornwall stone, the only notable difference is that series XVI is just a little more fusible and the glazes lie much flatter than in series XV, there being two glazes, Nos. 112 and 113, with Cornwall stone, that can be classed fair, where there are none with feldspar.

Series XVII and XVIII.

The same comparison will hold for series XVII and XVIII as for series XV and XVI, only series XVIII has two good glazes, Nos. 130 and 131, and one fair one, No. 132, where series XVII has none.

Series XIX and XX.

On comparing series XIX, feldspar, and series XX, Cornwall stone, it is seen that series XX is more fusible, and that the members of this series lie much flatter than in series XIX, there being no good glazes in series XIX and one good one, No. 148, and four fair ones, Nos. 149-152, in series XX.

Series XXI and XXII.

The only notable difference is that the first members of series XXII, with Cornwall stone, lie flat at cones 05 and 02, while the first members of series XXI, with feldspar, do not.

Series XXIII and XXIV.

The difference between XXIII and XXIV is very slight. Series XXIV, with Cornwall stone, lies a little flatter than series XXIII, with feldspar.

Series XXV and XXVI.

In these series as in the other series, when the equivalent of Cornwall stone and spar was low and the glazes good, the superiority of the Cornwall stone was very marked at low temperatures; when the Cornwall stone glazes would be perfect the corresponding spar glazes would be good in part of the tile, but would contain patches of undissolved material, and would not have a gloss equal to that of the stone glazes.

Comparison of the Cost, in Cents, Per Hundred Weight of the Glazes.

Materials	Cost per pound in cents.	Series I.			
		1st. Extreme		2nd. Extreme.	
		Per cent. Amts.	Cost	Per cent Amts.	Cost
Feldspar	0.60	20.92	12.552	16.04	9.624
Whiting	1.00	2.94	2.940	2.25	2.250
Mag. Carbonate.	4.50	0.05	0.225	0.04	0.180
Zinc Oxide	6.00	2.64	15.840	2.03	12.180
White Lead	5.50	58.96	324.280	45.19	248.545
China Clay	0.75	4.41	3.308	24.52	18.390
Flint	0.50	10.09	5.045	9.93	4.965
Total		364.190			296.137

Materials.	Cost per pound in cents.	Series II.			
		1st. Extreme.		2nd. Extreme.	
		Per cent. Amts.	Cost	Per cent. Amts	Cost.
Cornwall Stone...	0.70	35.44	24.808	26.31	18.417
Whiting	1.00	1.83	1.830	1.35	1.350
Magnes. Carbonate	4.50	.....	.....	.....	.....
Zinc Oxide	6.00	2.67	16.00	1.98	11.880
White Lead	5.50	59.54	327.40	44.19	243.045
China Clay	0.75	.....	.....	23.83	17.872
Flint	0.50	0.52	0.20	2.34	1.170
Total			370.388		293.734

Calculating the other series in turn in the same manner, and tabulating the cost thus obtained, we have,

Cost of Glazes, Per Hundred Weight.

Feldspar.			Cornwall Stone.		
Series	1st. Extreme	2nd. Extreme	Series	1st. Extreme	2nd. Extreme
1	$3.63	$2.96	2	$3.70	$2.93
3	3.52	2.83	4	3.58	2.87
5	3.35	2.54	6	3.38	2.67
7	2.93	2.49	8	3.01	2.64
9	2.82	2.38	10	2.89	2.52
11	2.65	2.23	12	2.72	2.35
13	2.38	1.88	14	2.46	1.93
15	2.24	1.77	16	2.32	1.82
17	2.12	1.67	18	2.19	1.71
19	2.83	2.25	20	2.91	2.30
21	2.68	2.12	22	2.75	2.16
23	2.54	2.00	24	2.60	2.04

To establish more fully the relative fusion points of the above mixtures, they were molded into cones, and those of similar chemical formula placed on slabs within two inches of one another, and burned in an updraft muffle kiln. In this way a very close comparison of the relative fusibilities of the mixtures was obtained. After burning a part of these, the point it was desired to determine was reached. The trials burned were series I and II, III and IV, VII and VIII, IX and X, XIII and XIV, XV and XVI. This confirmed, in most cases, the conclusions that had been reached from the same glazes when fired on tiles. In

all but five cases the Cornwall stone glazes fused earlier than the feldspar glazes. This difference was greatest in the upper members of series IX and X, where it amounted to 58°C; on the average for all glazes it was about 15°C. In the two preceding series, VII and VIII, which differed only in having a lower oxygen ratio, the greatest difference was in the glazes high in alumina, so that it was proven conclusively in this experiment that the Cornwall stone glazes were the more fusible ones.

The cases where the Cornwall stone mixtures were less fusible than the spar were the first two glazes of series IV, which melted 20° and 30°, respectively, higher than the corresponding glazes in series III. This was probably due to lack of clay to react with the lime, as in series II the first addition of clay made the mix more fusible. The other cases where the Cornwall stone glazes were less fusible, were in the last two members of series II, and the six members of series XVI. This apparent contradiction is unexplained.

Summary.

First. The shrinkage of raw lead glazes in drying is less when Cornwall stone is used as a glaze ingredient than in the case of feldspar. For this reason it might be possible to substitute Cornwall stone in place of feldspar, and overcome trouble with pulling or falling off of the glaze.

The physical reason for the above is that when feldspar is used, in order to bring it to the same equivalent of alumina as the Cornwall stone glaze, clay must be added. If this is introduced as raw clay, it has a large drying shrinkage, while in the case of the Cornwall stone most of the alumina is combined into a compound that is non-plastic, and hence the drying shrinkage is very small. So we must expect to find that with Cornwall stone we would get a glaze that would have a low drying shrinkage.

Second. When feldspar and Cornwall stone are used for the same equivalent of KNaO, the Cornwall stone produces the more fusible glaze. This distinction is most noticeable when the equivalent of KNaO is low.

The chemical constitution of Cornwall stone prohibits its use in high alkali raw lead glazes. When .15 equivalent KNaO is brought in by Cornwall stone, the alumina and silica run so high that the glazes becomes very refractory, and when melted do not flow readily enough to form a smooth covering.

The greater fluxing action of Cornwall stone may be explained if we consider it as a fritt prepared by nature. The alkalies and alkaline earths being already combined with the greater part of the alumina and silica that enter into the glaze are brought to fusion earlier, than in the case of the feldspar glaze, where in order to get the same composition, we must add to the feldspar, which supplies the alkali, a quantity of clay and flint to bring in the corresponding alumina and silica found in the Cornwall stone.

Third. The shrinkage of raw glazes in burning is less with Cornwall stone than with feldspar, so that the glaze will not bead up and be compelled to flow back and cover the ware to the same extent that it does with feldspar. This would make it possible to use Cornwall stone in a case where feldspar would not be possible. For, in the case of Cornwall stone, the glaze already covers more of the ware and does not have to flow as freely as in the case of the feldspar glaze.

Fourth. The cost of glazes made with Cornwall stone will exceed that of those made from feldspar by about 2 or 3%.

Fifth. If we were to substitute Cornwall stone for feldspar, pound for pound, we would expect to get a less fusible glaze, because in feldspar we have a mineral, that when compared with Cornwall stone contains less alumina and silica, and is about twice as high in percent of the fluxing elements. In the feldspar the greatest proportion of the material is in the form of a single mineral, and with Cornwall stone it is more evenly divided among several. So here again we would expect the feldspar glaze to be the most easily fusible.

DISCUSSION.

Mr. Stover: I would like to ask the members of the committee who got up the ceramic calculations, if in view of the light shed by this paper they consider it feasible to change the combining weight of Cornwall stone?

Mr. Binns: I have never used the data given in the manual on that point. The book was written some few years ago, and we have grown since then. I am perfectly certain that those figures are not accurate. I expect it would be quite difficult to find two samples of Cornwall stone quite the same, and we must analyze every sample if we do accurate work.

Mr. Orton: I, myself, was responsible for the Cornwall stone figure. I remember very well when preparing the manual that I had no good analysis of Cornwall stone at hand, and I drew on my memory for the principal proportions, the silica about 20, the alumina 2.5, and I assumed the RO elements to be made up of the alkalies. When Mr. Coulter brought this to me and showed the marked discrepancy between what he found and what the manual said, he wanted to know how I got that figure. On thinking it over I duplicated the original figures and came out about where I had, as given in the manual. The fundamental error in the calculation, of course, was due to the fact that I considered the fluxing elements of Cornwall stone to be made up of the alkalies, and this shows nearly as much lime and potash as of soda. That nearly doubles the amount of RO, and has the effect of cutting these elements in two.

I may say in regard to this paper that, of course, it is at a disadvantage in not being presented by the author, and not being condensed a great deal. It really represents a very large amount of patient work. Mr. Coulter put a great deal of time and industry into preparing the series, and it was founded on an opinion which he had gathered in dealing with some people, who told him that the Cornwall stone had given persistently better results in manufacturing raw lead glazes than they could get out of spar. He

asked me at the time whether I believed that represented the actual facts in the case, or whether it was a matter of opinion. We had no evidence at hand to prove one thing or the other, and he took up the question as his thesis in the college last year, with a view to running the question to earth and learning whether there was sufficient difference between the two kinds of material to make it fair to say that a Cornwall stone glaze, all things being equal, is better than feldspar. As you observe, he has covered a very wide range of glazes, and has demonstrated in those glazes the fact that Cornwall stone does give greater fusibility, flows out and makes a smoother glaze. Also, in the summary which he makes, he has entered into a discussion as to the probable causes of that, and it seems to me he has put his ideas in rather a fruitful shape.

Mr. Stover: Another point in the paper is in line with my experience in regard to the cracking in drying. I found in some trials where spar was used, that the glaze would crack before it was ready for the kiln; but by using the stone, (using the manual figures), the glaze made with the stone would not crack where the spar glaze would.

Mr. Orton: That difference comes in the alumina and amount of raw clay you have to add.

Mr. Geijsbeek: The conclusions at which Mr. Coulter has arrived, so far as substituting stone for spar is concerned, I find agree with my results. As a rule, if the glaze on a green body cracks in drying and peels off, I usually substitute, if not too much trouble, part of the spar with stone, in order to overcome the physical defects of the glaze. I use as much as I can of the stone, and I can get better results as far as handling the material is concerned.

Mr. Storer: What combining weights do you use?

Mr. Geijsbeek: I use the weight Prof. Orton figured up when I was in Columbus, which gives me at least some basis of comparison. We always get the stone in five ton lots. Sometimes we have quite a large job on hand, and the stone runs out in six or ten weeks, and we have to

change it. Another lot we would not have to change in six months.

Mr. Purdy: The most important feature developed in this paper is that in glazes where the alkali is low, Cornwall stone is never the best flux to use; but where the alkali is high, it matters not whether stone or spar is used. Where you have to use a large equivalent of stone or spar, the difference is not so pronounced.

I have at hand the melting points of these different bases, should anyone be interested to know.

Mr. Stover: Will they be in the paper when printed in the transactions?

Mr. Purdy: No; they are just my own.

THE RELATION BETWEEN THE COMPOSITION OF A PORCELAIN BODY AND ITS TOUGHNESS.

BY

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The toughness of porcelains, or their ability to stand wear and sudden impact, is a subject on which we have very little definite information. The relative value of commercial porcelains, when subjected to this kind of test, is shown in a large way by the demand in the markets for hotel china of particular manufacturers, who have been successful in producing a tough product. The life of some hotel china is two or three times as great as that of others of equally good appearance. Every one is so familiar with the kind of usage this class of goods receives, that it is scarcely necessary to emphasize the desirability for great toughness in the product.

In the electrical business, the element of toughness in the porcelains used is also of very considerable importance. This is increasingly manifested as higher and higher voltages are used in power transmission, on account of the increased losses and dangers incident to each break down. Where currents of large volume and lower voltage are carried, the cable for carrying them must be correspondingly increased in weight, thus subjecting the insulators to great tension and perhaps torsion. Sudden strains, such as caused by the swinging of the cables in a heavy wind, or the falling of branches of trees on them, makes a generous factor of safety greatly desired.

In the ordinary electrical porcelain manufacture, such as the production of lamp sockets, switch boards, cleats, tubes, rosettes, buttons, lightning arresters, etc., this element of resistance to abrasion and tension is likewise important. This class of material is frequently shipped in bulk, and the percentage of loss due to chipping of corners and edges is often high; this, of course, will happen

to some extent whatever the composition, but at the same time it is desirable to reduce it to the minimum.

The vitreous floor tile industry is beginning to feel the need of tougher products. The proportion of corners and edges exposed to wear, or liable to be exposed, in a piece of mosaic floor-tile work, is perhaps as large as in any other use to which a similar weight of porcelain material could be put. The ordinary wear on the surface of a tile floor is in some cases very severe indeed, especially in a district where considerable fine sand is carried into the building.

The writer is informed by the manufacturers, that they are willing to sacrifice some whiteness in their product for the sake of getting a body that will wear well. Incidentally this would seem to indicate a relation between the percentage of clay and the wearing quality of the product since feldspar, flint, and lime are usually the whitest of the raw materials used. The color of the clays when burned is more apt to be creamy rather than white,—this is especially true of the majority of ball clays. Any departure from the whitest porcelains obtainable is likely to be occasioned by using a larger per cent. of clay, or by substituting a very plastic ball clay for a feebly plastic, but whiter kaolin.

The technical literature on the subject of porcelains contains a great deal of valuable information on the working qualities and commercial desirability of the product of various compositions, but so far as the writer has been able to search, very little tangible data is available on the particular quality in question, namely, the ability of a given porcelain to stand gradual wearing, abrasion, and sudden impact.

It is believed that these three kinds of treatment do not necessarily require the same kind of product. For example, a very glassy porcelain will stand no end of frictional wear, (rubbing), but it will soon break down under abrasion, or a succession of sudden but very light blows, and it would probably be too brittle to resist the impact of a heavier blow.

This same kind of phenomenon is beautifully brought out in the comparative rattler tests on vitrified paving bricks, made according to the specifications of the National Brick Manufacturer's Association. It is almost always demonstrated that a very vitreous brick loses principally from the chipping off of corners and edges, and by breaking in two, thus exposing new corners and edges. On the other hand, a very soft brick, one that is not well vitrified, will wear into an egg-shaped mass, but seldom breaks. The happy medium is the brick that is well vitrified but at the same time not glassy in fracture. Such a brick usually shows the minimum loss, and this loss is due to a combination of chipping off of corners and edges, and gradual wearing away of the surfaces. They usually retain their rectangular form, and very often the trade name stamped in the side of the brick is legible after the test.

Dr. Seger's work on porcelains was of great value for the general information he has given us about the field of body composition, and the uses to which the various bodies were put. He examined seventeen samples of bodies from various parts of Europe and Asia, by the method of the rational analysis. By this method he was able to determine their mineralogical composition with sufficient accuracy to enable him to make very interesting comparisons between the different bodies. He found that the Japanese porcelains were very low in clay substance, some of them as low as 25 per cent., while the usual clay content of the European porcelains fell between 42 and 67 per cent. In his conclusions he says* "The bodies which I have used for decorated ware always contain plastic clays, as already stated above. These possess the character of the Japanese bodies examined, that is, they always were very high in quartz, according to the composition:

Clay substance	25 per cent.
Feldspar	30 per cent.
Quartz	45 per cent.

A porcelain thus compounded has tempting proper-

*Translation of Seger's Works, Vol. II, p. 723.

ties; it is very translucent, has only a slight shrinkage owing to the large quantity of non-plastic materials, a pleasant white or ivory-yellow color, and a much lower finishing temperature, about 1300°, or cone 8 to 10."

"In spite of this I do not recommend it for the production of all kinds of porcelain. The much lower temperature which it requires and which causes it to be less expensive, cannot alone decide its use. It, like all translucent porcelains of Asia, *is more sensitive to a quick change in temperature and to a sharp knock than our ordinary porcelain, richer in alumina,* and this peculiarity alone would keep it from general application."

Watts, in his paper on Electrical Porcelain*, reaches the following conclusions on the quality of toughness: "From a study of the abrasion tests it is very apparent that with potassium oxide alone as a flux, and even with a moderately high clay substance, we obtain a brittle and weak porcelain. When as low as 20 per cent. of the potassium oxide is replaced by calcium oxide, we find the product changed to a tough and well vitrified body."

General Scope of Experimentation in this Field.

There are two principal modes of attack in undertaking to study the relation between the composition of porcelains and their toughness.

One of these methods may be called the analytical, the other the synthetic. In pursuing the former, we would determine as nearly as possible, by chemical analysis, the constitution of various porcelain bodies now on the market, and subject the same bodies to comparative abrasion tests. A correlation of the results so obtained would doubtless show some very interesting facts about the differences in composition and wearing qualities of the well known brands of porcelain. This line of attack is, however, very difficult for two reasons: First, difficulties and uncertainties entering into the chemical work. In judging the composition from analytical data, the alkalies and lime would, of course, be the basis of calculation. We would

*Trans. American Ceramic Society, Vol., IV., p. 125.

have to assume that all the alkalies were brought in by feldspar, and that all lime had been added as whiting. The clay content would be calculated from the alumina it had supplied—this would be the total alumina minus that belonging to the spar. It will be seen at once that while such a tentative procedure would doubtless give some valuable results, it is always open to more or less objection, because it is based largely on assumptions. However, these assumptions are true in the main, and would therefore give conclusions of real value and importance. Second: The even greater difficulty in securing from commercial porcelain ware, pieces of sufficiently similar shape and thickness to make their abrasion tests comparable one with the other.

In pursuing the synthetic mode of attack, however, it is evident that all of the variables are more completely under the control of the experimenter. He can put together what constituents he will; and he can make his trial pieces whatever shape and size he wishes; finally, he can burn his product at any desired temperature.

It occurs to the writer that this last item is one of importance. Two bodies of the same composition may show vastly different degrees of toughness, due to unlike temperature treatment. For example, in some experiments carried on by the class in ceramics at the Ohio State University in February, 1905, it was found that a porcelain of the composition:

$$\left.\begin{array}{l} 0.18\ K_2O \\ 0.12\ CaO \end{array}\right\}\ 1\ Al_2O_3\ \left\{\ 4.03\ SiO_2\right.$$

burned at cone eight, showed a loss of 2.1% when rattled in a wet ball mill for one hour, while samples of the same body, burned at cone twelve, and subjected to a precisely similar test, lost 4%. Both were true porcelains and were non-absorbent. It is evident that this porcelain was more nearly at its best at cone eight than at cone twelve.

On the foregoing grounds, this investigation was based on the synthetic process.

Plan of the Work.

The porcelains to be considered in the following pages are theoretically 30 in number. They are divided into three series of ten each. These series differ from each other in clay content only. They are 40, 50 and 60 per cent. clay. Each series is divided into two groups, one made of pure feldspar porcelains, the other consists of lime-feldspar porcelains. The calcium oxide and potassium oxide are maintained throughout in the relation of 0.4 equivalent of lime to 0.6 potassium oxide.

It was stated above that "theoretically" there were 30 different compositions—actually there are only 19. This decrease in the number is occasioned by the plan of increasing the calcium oxide and potash content, which in each series starts with .25 equivalent and changes by increments of .05 equivalent. In some cases, this very soon leads us out of the range of possible compositions. For example, it is impossible to make number 40-5, which would contain 0.45 potassium oxide and must contain 40% clay substance. The table given below shows the composition, and series numbers of the 19 different bodies. If it is borne in mind that the first five numbers in each series of ten, refer to the feldspar porcelains, and the numbers from 6 to 10 refer to those whose RO is made up of potash and lime, there will be little trouble in associating the number with the composition.

The justification for making up a lot of porcelains, the different series of which are apparently so poorly balanced in numbers, is as follows:

In the first place it was desirable to make only mixtures that would be commercially workable; hence, the clay content was set between the limits of 40% and 60%.

Secondly, it was desired to make the consecutive numbers in each group exactly comparable with the corresponding number in the other groups. In other words, the increments in the RO content were maintained constant at .05 equivalent.

All of the trials were burned to cone 10 in a commer-

cial kiln. This temperature was chosen because it was thought to be about the minimum temperature at which true porcelains, suitable for hotel china and table ware, could be produced. It is higher than that used by some makers of electrical porcelain, but is in every day use in the floor tile industry. In fact, it is believed that cone 10 will probably suit a greater number of commercial porcelains than any other one temperature.

TABLE OF FORMULAE.

Forty Per Cent. Clay Series.

No.	K_2O	CaO	Al_2O_3	SiO_2
40-1	.25	—	1	5.51
40-2	.30	—	1	4.92
40-3	.35	—	1	4.34
40-4	.40	—	1	3.76
40-6	.15	.10	1	6.53
40-7	.18	.12	1	6.14
40-8	.21	.14	1	5.75
40-9	.24	.16	1	5.36
40-10	.27	.18	1	4.97

Fifty Per Cent. Clay Series.

No.	K_2O	CaO	Al_2O_3	SiO_2
50-1	.25	—	1	3.90
50-2	.30	—	1	3.42
50-6	.15	.10	1	4.70
50-7	.18	.12	1	4.38
50-8	.21	.14	1	4.05
50-9	.24	.16	1	3.73

Sixty Per Cent. Clay Series.

No.	K_2O	CaO	Al_2O_3	SiO_2
*60-1	.25	—	1	3.02
60-6	.15	.10	1	3.48
60-7	.18	.12	1	3.20
60-8	.21	.14	1	2.93

*Contains 58% clay. Maximum amount possible with this RO.

Method of Manufacture.

The extreme members of each group were weighed out on a torsion balance, in batches of three kilograms each.

This dry material was placed in a porcelain ball mill, together with twenty pounds of flint and porcelain pebbles and exactly eight pounds (3629 grams) of distilled water. The charge thus prepared was milled for exactly one-half hour to accomplish thorough mixing but little grinding. The porcelain mills used measured ten inches in diameter by thirteen inches deep, and were run at fifty-five revolutions per minute. The charge of pebbles was kept constant in weight throughout the work, and was made up of three parts of porcelain marbles, averaging three-fourths inch in diameter, and one part of flint pebbles, averaging one and one-fourt inch in diameter. Thus it will be seen that the total charge of each mill was kept constant, and all charges were milled exactly the same length of time. Great care was taken with this part of the work to insure comparable results. All bodies were screened through a 100 mesh brass screen. The detritus was very small in amount, and was composed chiefly of wood fibre and grains of sand from the ball clays.

In removing the slip from the mill, no additional water was used. This procedure gave three kilos dry weight and 8 pounds (3629 grams) of water, or a total of 6629 grams of slip. It follows that 6629 divided by 3000, or 2.21 is the factor that must be used in reckoning the dry constituent or solids in any quantity of slip. Thus 2.21 grams of slip will always give one gram of solids.

After considerable experience with the other method of determining the solids, namely, that of evaporating a given weight of slip to dryness, the writer has decided in favor of the method described above.

The extremes of each group were blended by weight in slip form to produce the intervening numbers of the group. The complete calculation for the first group is given below. Attention is called to the fact that in all

blends the difference in the molecular weights of the extremes was taken into account. The lighter mixture molecularly will have more molecules or equivalents per pound than the heavier, consequently, in each case the extreme with the heavier molecule is multiplied by a factor greater than one, in order to give the pounds weight corresponding to the required equivalents.

Calculation of the 40% Clay Group.

Body 40-1.

Formula: $.25\ K_2O\{1\ Al_2O_3\}\ x\ SiO_2$

The value of x is determined by the specification that the clay is to be 40% of the total.

Required:

$$.25 \text{ eq. spar} \times 557 = 139.2 \quad (1)$$
$$.75 \text{ eq. clay} \times 258 = 193.5 \quad (2)$$
$$x-(1.50+1.50) \text{ eq. flint} \times 60 = A \quad (3)$$

Total=molecular weight of the body.

Since the clay is to be 40 per cent. we have 193.5÷molecular weight of body=40% or .40. Therefore the molecular wt. of the body=483. We can now get the value of A:

$$483-(139.2+193.5)=150.3.$$

Substituting in equation (3) we have

$$x-(1.50+1.50) \text{ eq. flint} \times 60 = 150.3$$

or 2.51 equivalents flint are required

and x=sum of 1.50 + 1.50 + 2.51 + 5.51.

Our completed formula is now:

$$.25\ K_2O\ \{\ 1\ Al_2O_3\ \}\ 5.51\ SiO_2.$$

0.25 eq. spar	× 557 = 139.2	÷ 483 =	28.8%
0.75 eq. clay	× 258 = 493.5	÷ 483 =	40.0%
2.51 eq. flint	× 60 = 150.3	÷ 483 =	31.2%
	483.0		100.0

The clay used in this work was derived in equal parts from the following materials: Tennessee Ball No. 3, English Ball, Florida Kaolin, and English china clay. Half the clay is china clay, and half is ball clay; half is American material and half is English. The object in using an assortment of clays was to approach as nearly as possible

to the well established practice among manufacturers, of using several clays in order that slight variations in any one of them may not unbalance the body mix; or in order that the sum total of variations in the several clays may keep the average clay content fairly uniform.

The batch weights for three kilograms of body 40-1 is as follows:

Spar	28.8%	=864 grams
Flint	31.2%	=936 grams
Clay	40.0%	grams
Tennessee Ball No. 3	10.0%	=300 grams
Florida Kaolin	10.0%	=300 grams
English Ball Clay	10.0%	=300 grams
English China Clay	10.0%	=300 grams
		3000 grams

By a similar method body 40-4 was found to have the formula:

$$.40\ K_2O\ \{\ 1\ Al_2O_3\ \}\ 3.757\ SiO_2,$$

the molecular weight being 387.

Blending.

To produce body 40-2 formula:

$$.30\ K_2O \quad 1\ Al_2O_3 \quad x\ SiO_2.$$

The blending is done on the basis of the RO.

Body 40-4 has	.40 K_2O.	Body 40-1 has	.25 K_2O
Body 40-2 requires	.30 K_2O.	Body 40-2 requires	.30 K_2O
	.10 available		.05 needed

If we blend these two extremes in the inverse ratio of the RO differences between them and the body required, we will produce body 40-2 with .30 K_2O.

Therefore, we use 2 molecular parts 40-1 and
1 molecular part 40-4,

i. e. $\frac{2}{3}$ molecule of No. 40-1 and
$\frac{1}{3}$ molecule of No. 40-4.

Proof:— $\frac{2}{3}$ of [.25 K_2O (1 Al_2O_3) 5.51 SiO_2] plus
$\frac{1}{3}$ of [.40 K_2O (1 Al_2O_3) 3.757 SiO_2]
equals [.30 K_2O (1 Al_2O_3) 4.92 SiO_2]

which is body 40-2.

From the molecular proportion to get the proportion by weight we proceed as follows:

Body 40-1 has a molecular weight of 483.

Body 40-4 has a molecular weight of 387.

Since 40-1 is the heavier molecule, we must use more pounds of this body than we do of the body 40-4 in order to get an equal number of molecules,

i. e. $483 \div 387 = 1.25$.

For 1 part by weight of 40-4 use 1.25 parts by weight of 40-1.

Now the moisture factor of our slips is kept uniformly at 2.21.

Blend:

No.	Molecular parts	Molecular factor	Parts by wt. dry	Moisture factor	Weight of slip
40-1	2	× 1.25 =	2.50	× 2.21 =	5.52
40-4	1	× 1.00 =	1.00	× 2.21 =	2.21
40-2					7.73

These weights were multiplied by 400 to give a large enough quantity of slip.

40-1. 5.52 grams × 400 = 2208 grams
40-4. 2.21 grams × 400 = 884 grams

40-2. 3092 grams

After thorough blending by stirring, the bodies were dried until plastic in heavy plaster molds. On removing the plastic mass from the molds, care was taken to scrape off and discard any adhering particles of plaster.

The trial pieces were cut out with a round cake cutter and expressed from it onto wooden pallets by means of a tin disc just large enough to fit the inside of the cutter. The whole process of making the trial pieces was very similar indeed to the house wife's procedure when she makes biscuits. The clay was batted out on a small marble slab between wooden guides about five-eighths of an inch high, to control the thickness of the trial. The plastic lump was brought to exactly the right thickness, by use

of a wooden roller on top of the guides mentioned above. By such a procedure it was possible to cut the very center out of a piece of plastic clay, whose mass was three or four times that of the trial piece itself. This arrangement, it was thought, would give the best possible structure, reducing to the minimum the bad effects due to bubbles and laminations.

The trial pieces were covered with cloths and slowly dried in an unheated room. About 72 hours was required to completely dry a set of trials by this method.

The trials were then biscuited at cone 010 in a small updraft muffle kiln belonging to the Ceramic Department of the Ohio State University. The object of this preliminary burn was simply to dehydrate the bodies, and make them hard enough to stand transportation. The complete lot of some 200 trial pieces was then taken to a porcelain factory, and placed in saggers in a twenty-foot down draft gas-fired kiln. Four saggers wer used, and cones 9 and 10 were placed in the middle of each sagger. The duration of the burn was 104 hours, and cone 10 was well down in each sagger. It is believed that these trials had as nearly uniform temperature treatment as it is possible to get, as they were treated to regular commercial conditions in a plant where great care and skill is used in burning.

Appearance of the trials when burned.

Every one of the 19 bodies was very hard, and to all appearances a true porcelain. In the 40% clay series, Nos. 1 and 6 are very hard, and show a fair degree of translucency. This property increases in the succeeding numbers in both the feldspar and the feldspar-lime group, until in No. 40-10 we have a very hard, glassy porcelain. When held before a strong light in a dark room, it is possible to see the shadow of one's fingers through a tile of this body one-fourth of an inch thick. In fact, all but the first two numbers in this series (40-1 and 40-6) will transmit some light through one-fourth inch thickness.

All the members of the 50% clay series are distinctly less stony than the corresponding numbers of the series

just described. The highest numbers, namely, Nos. 50-8 and 50-9, are slightly translucent through one-fourth inch thickness. Strange to say, No. 50-8 is more translucent than No. 50-9. All the bodies of this series give evidence of being good, tough, strong porcelains.

The members of the 60% clay group are hard, stony porcelains, and with the exception of No. 60-1 are not translucent through one-fourth inch thickness. No. 60-1, however, is quite translucent through this thickness. The fact that 60-6 having the same amount of RO fluxes, but part of them being lime, does not show translucency, seems to strengthen the observation of Watts*, who found that translucence is reduced by an addition of calcium oxide.

In all three series the feldspar-lime members are whiter than the corresponding feldspar members. This fact was noticed by three observers independently of each other.

Remarks on the General Appearance and Structure of the Porcelains as Shown by their Fracture.

40-1. This body has a dull stony fracture, only slightly translucent.

40-2. Has somewhat stony fracture but shows some glassiness.

40-3. More glassy, more translucent at the edges.

40-4. More glassy fracture, most translucent of the group.

In this group with the increase of the potassium oxide, we notice a steady change from a dull, stony, poorly translucent porcelain, (No. 40-1), to a translucent porcelain with a glassy fracture, (No. 40-4).

40-6. Has a dry looking, stony fracture, much more coarsely granular, when viewed under a small glass, than 40-1.

*Trans. A. C. S. Vol. IV, p. 125.

40-7. Has a stony fracture and appears more dense in structure than 40-6. The fracture glistens slightly. Translucency is better than No. 40-6.

40-8. A very hard dense porcelain with stony fracture, glistens more than No. 40-7, is slightly more translucent.

40-9. Has very dense structure, glistens more and is decidedly more translucent than No. 40-8.

40-10. This porcelain has much the same quality of fracture as No. 40-3 (.35 K_2O) i. e., it is very dense and shows some glassiness.

This group, compared with the feldspar group, is more stony throughout, and changes from a coarse structure with a dry fracture, (No. 40-6), to a very dense body with a slightly glassy fracture, (40-10). The translucency progresses with the increase in the RO fluxes.

50-1. Has the same quality of fracture as shown in No. 40-3. There is a marked contrast between this body and No. 40-1, the latter being decidedly stony, while the former shows a conchoidal glassy fracture.

50-2. Shows a very conchoidal and glassy fracture, and is noticeably more translucent than the preceding number. This body is much more glassy than No. 40-4, the highest in potash of the 40% clay series. In other words, with 50% of clay and 0.30 equivalent potassium oxide, we have a higher degree of vitrification and a better quality of translucency than with 40% clay and 0.40 equivalent potassium oxide.

50-6. Shows a very fine stony fracture, resembling No. 40-9, but seems to have a close structure.

50-7. Very similar to 50-6, but has a slightly more glassy fracture.

50-8. The fracture of this porcelain is more glassy and the structure seems to be finer than No. 50-7.

50-9. Has fracture very much like 40-3, it is more glassy than No. 50-7.

The four members of this group show an increase in lustre or glassiness, and the structure becomes closer as the RO fluxes increase.

60-1 has a very smooth, glassy fracture, somewhat like No. 40-4 but very much smoother. Compared with No. 50-1, its fracture is smoother and more glassy. This body is very hard and dense and quite translucent.

60-6. Here again we have a body containing a small amount of lime, presenting a more stony structure than the corresponding feldspar member, No. 60-1. This body appears much finer in structure with smoother and more glassy fracture than No. 50-6.

60-7 has a smooth, glassy fracture, similar to No. 60-6.

60-8. Very similar to No. 60-7.

The members of this group appear very much alike. The texture seems to become smoother and the glassiness more pronounced as the RO fluxes increase.

Comparing the corresponding numbers of the three feldspar groups, a remarkable increase in the degree of vitrification, fineness of texture, and glassiness is noted with the increase in clay. The same phenomenon is clearly seen in the feldspar-lime groups, i. e.:

No. 40-6. Coarse, dull, stony fracture.

No. 50-6. Dense, slightly lustrous, stony fracture.

No. 60-6. Very dense, quite lustrous fracture, much finer in texture.

Bodies Nos. 40-7, 50-7 and 60-7 exhibit the same kind of change with the increase in clay. This is also clearly traced in Nos. 40-8, 50-8 and 60-8.

Shrinkage and Absorption.

The following table shows the shrinkage and absorption of the various bodies. The shrinkage figures are the averages of three measurements in each case, but owing to the fact that the test pieces were small, 6.3 centimeters (2.48 inches) in diameter, and that considerable variation was noted in pieces of the same composition, these shrinkage results are not regarded as very exact.

Table of Shrinkage and Absorption.

No.	Drying Shrinkage	Burning Shrinkage	Total	Per Cent. Absorption
40-1	4.7%	9.0%	13.7%	0
40-2	4.7%	9.7%	14.4%	0
40-3	4.7%	9.3%	14.0%	0
40-4	4.7%	9.7%	14.4%	0
40-6	4.7%	9.0%	13.7%	0.4
40-7	4.7%	9.0%	13.7%	0
40-8	4.7%	9.0%	13.7%	0
40-9	4.7%	8.2%	12.9%	0
40-10	4.7%	8.2%	12.9%	0
50-1	6.3%	10.4%	16.7%	0
50-2	6.3%	11.6%	17.9%	0
50-6	6.3%	9.9%	16.2%	0
50-7	6.3%	9.7%	16.0%	0
50-8	6.3%	10.3%	16.6%	0
50-9	6.3%	9.5%	15.8%	0
60-1	6.3%	13.4%	19.7%	0
60-6	7.9%	12.0%	19.9%	0
60-7	7.9%	10.8%	18.7%	0
60-8	7.9%	11.2%	19.1%	0

Note:—Shrinkage calculated on wet length as unity. Trials wer soaked 48 hours in water for absorption test.

These results, however, are approximately correct and show an increase in shrinkage with every addition of clay. They seem to indicate also that the lime-feldspar porcelains have a slightly lower shrinkage than the corresponding feldspar bodies.

In making the absorption test, the pieces were placed on edge in a pan of water with a portion of their surface exposed, to permit the escape of air, provided any of the bodies should be porous.

Development of a Suitable Abrasion Test.

It was desired to develop a test that would subject the bodies to both gradual abrasion and sudden impact. The latter force, however, should be kept down to a point that would not break the sound pieces in two, but would at the same time bring out the relative brittleness of the bodies to be tested.

A round iron ball mill, run at 35 revolutions per minute, was available for this work. The section of this mill parallel to the axis is elliptical, i. e., the mill is somewhat turnip-shaped. The inside diameter perpendicular to the axis is 24 inches, the width is 7½ inches. It was decided to try the effect of various kinds of charges and different weights of the abrasion material. A quantity of two inch white, vitreous, hexagonal floor tile was procured and used in developing a test of the proper severity.

The first trial was made with the mill about three-fifths full of flint pebbles, averaging 1¼ inches in diameter. The weight of this charge was 99 pounds. Six tiles were placed in the mill and revolved for 10 minutes. The tiles were literally chipped to pieces, and had lost 24% of their original weight. It was evident that the impact feature was entirely too great. Accordingly 25 pounds more of pebbles were added, making the mill about four-fifths full. A ten minute trial on six more tiles showed a very much smaller amount of chipping, and the loss was found to be only 2.1%. This seemed to be more encouraging, so the test was continued for fifty minutes, making a total of one hour. The pieces were taken out of the mill every ten minutes for the first half hour and weighed. The loss was as follows: Ten minutes, 2.1%; twenty minutes 3.0%; thirty minutes 5.3%; sixty minutes 6.36%. In the hope of getting a reasonably good check on this result, another lot of the same tiles was put into the mill and rattled continuously for one hour. They showed a loss of only 3%. In the preceding test, it had been observed in removing the tiles from the mill that they showed a tendency to work their way to the center of the mill, and become almost stationary, with one flat surface against the end surfaces of the mill. When in this position they would receive very little punishment. This is probably what happened in the one hour continuous run.

After considerable further experimenting with flint pebbles, it became evident that the accidental feature was entirely too great, and that comparable results could not

be expected if pebbles were to be used for the abrading material.

Having given up the pebbles, a trial was made with iron jack-stones, which gave much better results. These jack-stones, such as are used in the foundries for rattling castings, were one and one-half to one and five-eighths inches in diameter, and numbered thirteen to a pound. Two hundred pounds of this material, together with fifteen pounds of flint pebbles—to introduce the accidental element of sudden impact—were put into the mill. This charge gave much more nearly the desired quality of the test, i. e., the abrasion feature was the principal element, while at the same time the element of impact was also present.

Accordingly, two lots of six tiles each were rattled alternately for periods of fifteen minutes until each lot had had a total of one hour in the mill.

The results were as follows:

Time	Loss in Per Cent.	
	A	B
15 minute test	5.55%	5.28%
30 minute test	9.25%	9.10%
45 minute test	9.52%	10.45%
60 minute test	11.00%	11.15%

These results were sufficiently comparable to warrant proceeding with the testing of our regular trial pieces.

The results of the abrasion tests, as carried out, are shown in the following table. The loss is given in percents of the original weight, at the end of fifteen minute intervals. The tests are based on six pieces of each body:

Forty Per Cent. Clay Series.

No.	K_2O	CaO	Al_2O_3	SiO_2	15 Min.	30 Min.	45 Min.	60 Min.
40-1	0.25	....	1.0	5.51	1.93	3.27	4.14	4.62
40-2	0.30	....	1.0	4.92	0.68	0.97	1.66	1.95
40-3	0.35	....	1.0	4.34	1.57	2.66	3.54	4.33
40-4	0.40	....	1.0	3.76	6.92	9.14	10.75	12.35
40-6	0.15	0.10	1.0	6.53	0.30	0.58	0.73	0.88
40-7	0.18	0.12	1.0	6.14	0.58	0.93	1.62	1.97
40-8	0.21	0.14	1.0	5.75	1.17	1.85	2.73	3.31
40-9	0.24	0.16	1.0	5.36	2.12	2.98	4.43	4.81
40-10	0.27	0.18	1.0	4.97	2.16	3.90	....	5.14
Fifty Per Cent. Clay Series.								
50-1	0.25	....	1.0	3.90	1.73	2.45	2.85	3.46
50-2	0.30	....	1.0	3.42	5.35	11.00	13.50	15.13
50-6	0.15	0.10	1.0	4.70	1.95	2.88	3.50	3.70
50-7	0.18	0.12	1.0	4.38	1.96	2.68	4.12	4.95
50-8	0.21	0.14	1.0	4.05	1.57	2.62	4.51	6.30
50-9	0.24	0.16	1.0	3.73	2.90	4.97	6.10	7.34
Sixty Per Cent. Clay Series.								
60-1	0.25	——	1.0	3.02	——	14.55	17.85	19.60
60-6	0.15	0.10	1.0	3.48	2.67	3.78	5.22	6.45
60-7	0.18	0.12	1.0	3.20	4.60	6.73	8.30	9.75
60-8	0.21	0.14	1.0	2.93	1.79	5.37	9.08	10.45

These results are plotted on the following curve sheets. There is one sheet for each of the three series. A study of these curves reveals some very interesting tendencies. The character of the curve indicates the character of the porcelain it represents; a sudden rise in the curve corresponds to rapid loss due to chipping. This occurs with the brittle glassy porcelains.

The Forty Per Cent. Clay Series.

The curves for this series indicate that as the RO increases, and a greater degree of vitrification is developed, the porcelains become weaker. In the feldspar group, we note that 0.25 equivalent of potassium oxide alone is not enough flux to develop the best porcelain. We have observed above that this porcelain was quite stony, while 0.30 equivalent of potash gives a strong porcelain, but every addition thereafter weakens the body. Number 40-4 is very brittle, and, therefore, loses rapidly during the early stage of the test due to chipping.

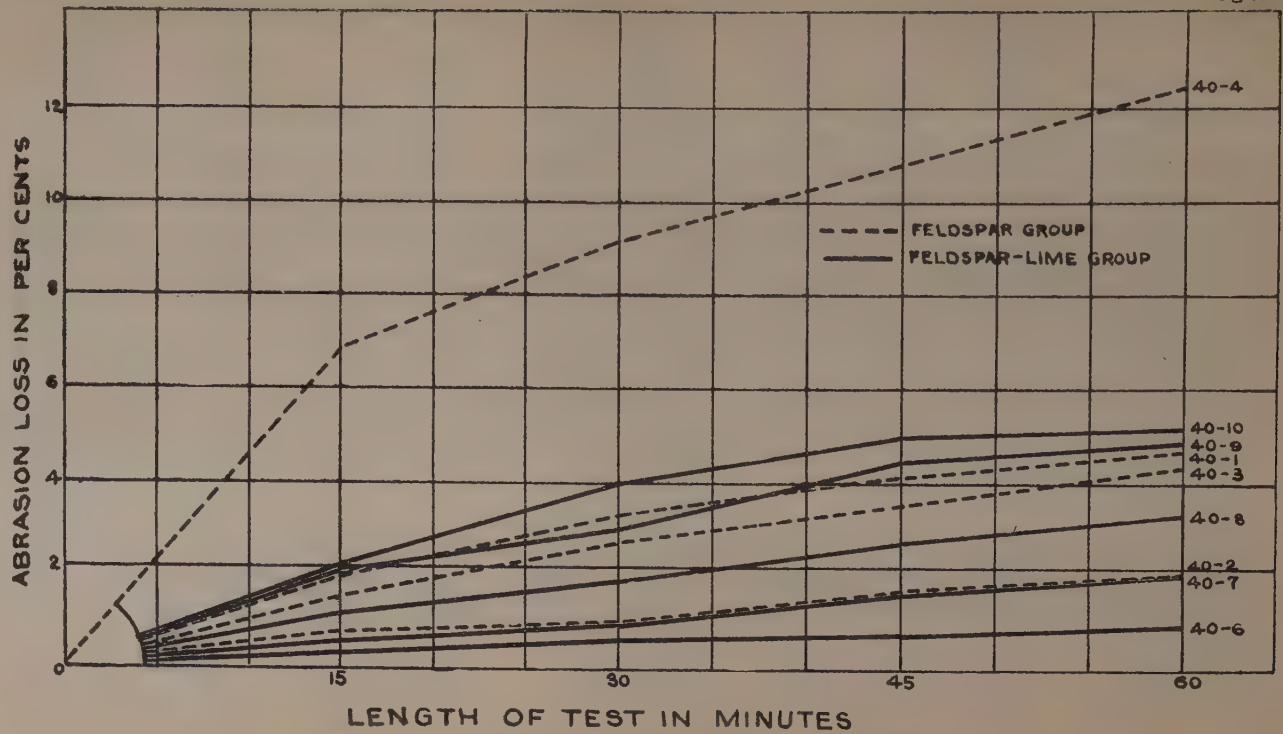


Fig. 1. Abrasion Results of Forty per cent. Clay Series.

In the lime-feldspar group, we note that No. 40-6, containing 0.25 K_2O, CaO is the strongest of the lot; every addition of RO fluxes, while it improves the appearance of the body, seems to reduce its resistance to abrasion. It will be noticed that the curves for this group are very similar and quite regular in their behavior. No. 40-6 is by far the coarsest and most granular porcelain in the whole lot of nineteen bodies; it is the only one in the whole experiment that shows any absorption, and is at the same time the toughest as shown by these tests.

Fifty Per Cent. Clay Series.

The most striking feature perhaps in this series is the remarkable difference between Nos. 50-1 and 50-2. It seems strange that an increase of .05 K_2O could cause so great a change in the character of a body.

In the lime-feldspar group we have a repetition of the facts as indicated in the forty per cent. clay series. No. 50-6, the lowest in flux, shows the greatest degree of toughness, Nos. 50-7, 50-8 and 50-9 are progressively weaker. This relation is maintained in three of the four observations. At the thirty minute observation Nos. 50-6, 50-7 and 50-8 are very close to each other, but No. 50-9 shows very noticeably more loss than any of the rest.

Sixty Per Cent. Clay Series.

The curve for No. 60-1 indicates a very weak, brittle porcelain, in spit of the fact that this body showed a very excellent degree of vitrification, and was to all appearances a good porcelain.

The lime-feldspar curves of this series are not as regular in their behavior as those of the two preceding series. This is due, no doubt, to the fact that all of the porcelains of this group are quite brittle, and the selective action of the test is not as nice as with the tougher bodies. In other words, the accidental feature of impact has greater influence here than with the corresponding members of the other series. In spite of this fact, however, we note that in two of the four observations, the abrasion losses increase in the order of the increase of the RO fluxes.

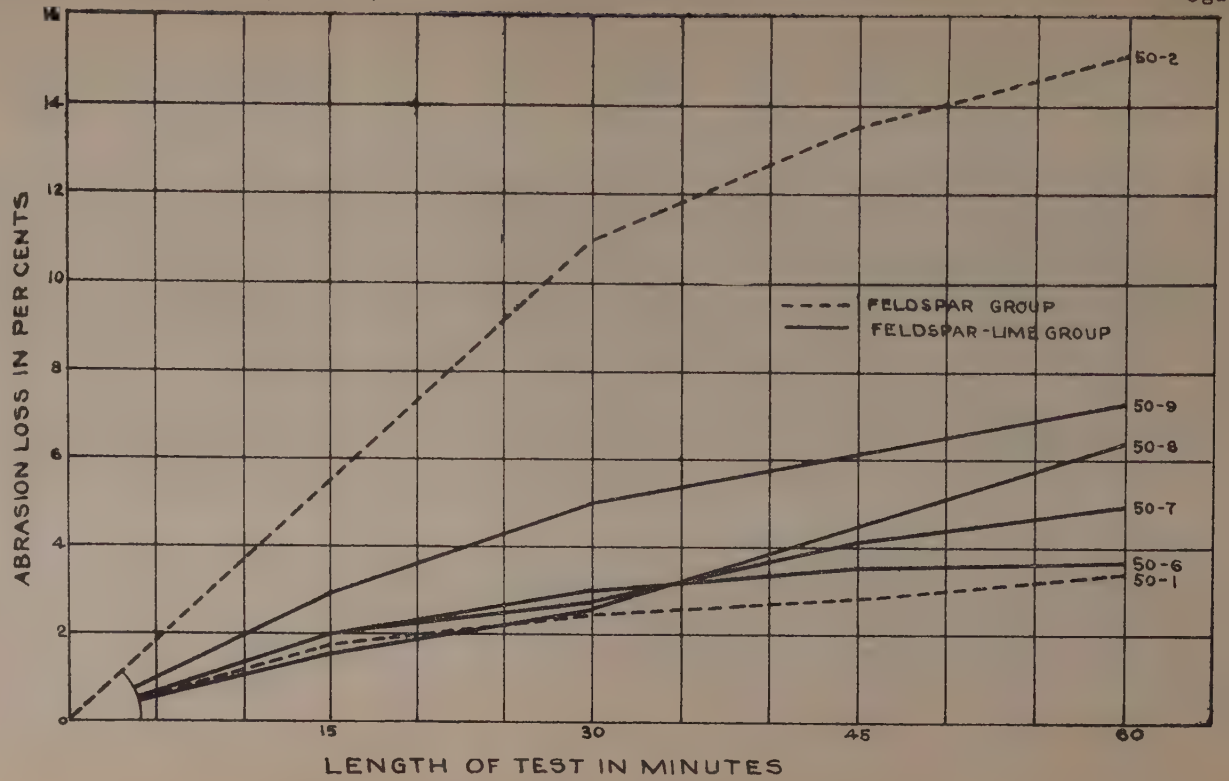


Fig. 2. Abrasion Results of Fifty per cent. Clay Series.

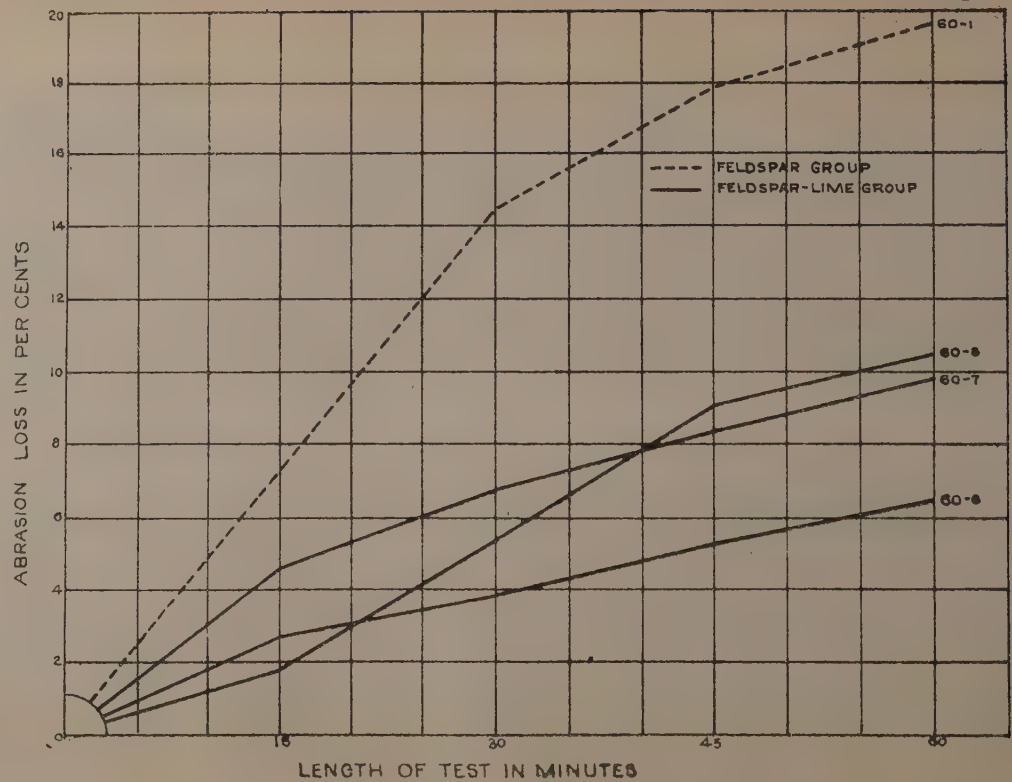


Fig. 3. Abrasion Results of Sixty per cent. Clay Series.

Discussion of the Curves, Showing Effect of Increase of Clay with Constant RO.

With a single exception, No. 40-1, 0.25 K_2O, we note that every increase in clay, with a given RO, diminishes the wearing quality of the porcelain—as shown by these tests. The exception, No. 40-1, has already been discussed; it is believed that this amount of RO, (.25 equivalent), consisting entirely of potassium oxide, is not sufficient to develop the toughest product, at this temperature.

We regard clay as one of the most refractory of our whiteware body ingredients, hence, it may be imagined that with a constant RO content, every addition of clay would make the body more refractory, and cause a poorer degree of vitrification. This is not the case, however, within the field of composition covered by this experiment; in fact, quite the reverse is true. In every instance a higher clay content with a given RO has produced a finer degree of vitrification and translucency. (See examination of the fractures above.)

The following table shows the percentage composition of the porcelains tested, together with their total abrasion losses for a one hour period.

Table of Percentage Compositions and Abrasion Losses.

No.	Feldspar	Whiting	Flint	Clay	Abrasion loss 1 hr.
40-1	28.80%	———	31.20%	40%	4.62%
40-2	37.15%	———	22.85%	40%	1.95%
40-3	46.50%	———	13.50%	40%	4.33%
40-4	57.60%	———	2.30%	40%	12.35%
40-6	15.20%	1.80%	42.90%	40%	0.88%
40-7	19.20%	2.26%	38.60%	40%	1.97%
40-8	23.00%	2.75%	34.25%	40%	3.31%
40-9	27.20%	3.23%	29.60%	40%	4.81%
40-10	32.00%	3.80%	24.20%	40%	5.14%
50-1	36.00%	———	14.00%	50%	3.46%
50-2	46.30%	———	3.70%	50%	15.13%
50-6	19.10%	2.28%	28.70%	50%	3.70%
50-7	24.00%	2.70%	23.30%	50%	4.95%
50-8	30.00%	3.60%	15.60%	50%	6.30%
50-9	34.10%	4.09%	11.80%	50%	7.34%
60-1	41.60%	———	1.00%	58%	19.60%
60-6	22.50%	2.80%	14.50%	60%	6.45%
60-7	28.50%	3.38%	8.12%	60%	9.75%
60-8	34.80%	4.20%	1.00%	60%	10.45%

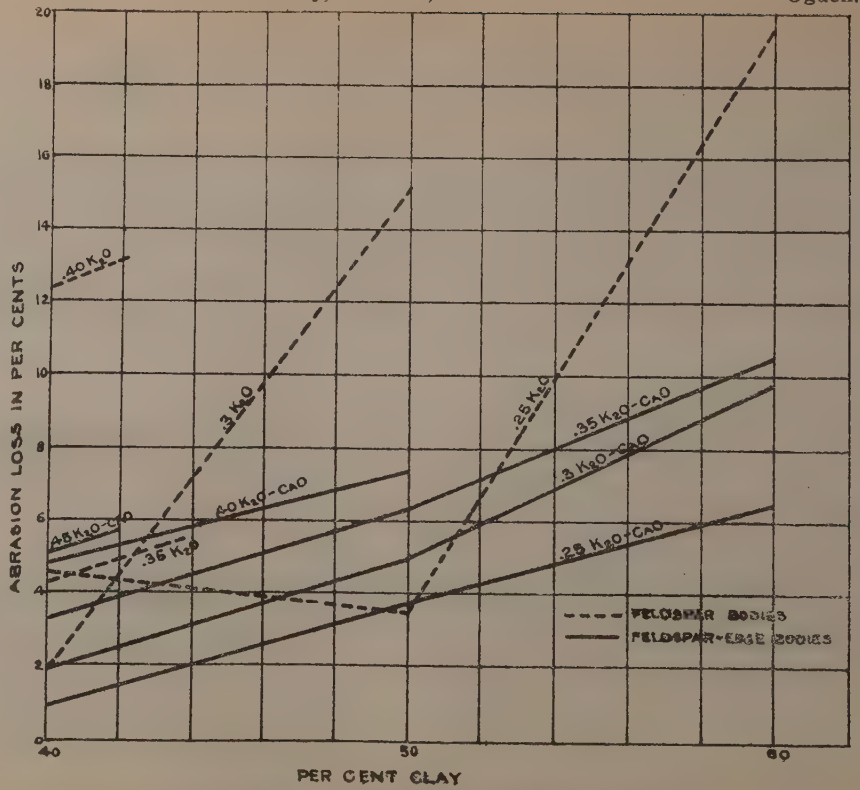


Fig. 4. General Comparison of Abrasion Results.

Summary.

The porcelains tested in this work were all burned at one temperature, cone 10. While all of them are well matured porcelains, it cannot be said that they are all at their best at this temperature; it is certain, however, that none of them have been carried to the point where they would not pass for a well matured body, and that none of them have developed porosity due to incipient fusion. *Purdy has given absorption tests on vitreous tile, which showed the following results:

Slightly underfired	1.349%
Normal	0.185%
Slightly over fired	1.090%

indicating that when tile are carried beyond complete vitrification, i. e., where incipient fusion has set in, the body will develop porosity.

This condition does not prevail in any of the porcelains here presented.

In all technical investigations, the results obtained by a single experimentor can not, as a rule, be said to be conclusive; a correlation of the results obtained independently by two or more investigators, and a close agreement among them, is usually desired before any sweeping conclusions can be drawn.

The principal limitation of this experiment is that only one temperature was employed. The following raw materials were used: Brandywine feldspar, Golding's flint, English ball clay (the trade number of this clay is not known), English china clay, and English whiting.

All the evidence produced in this work seems to warrant the following statements:

First. That every increase in the RO fluxes contributes to the translucency and fineness of structure. In all cases, with the single exception of No. 40-1, the greatest degree of toughness has been shown in bodies with 0.25 RO, the degree of toughness decreasing as the RO fluxes increase.

*Trans. A. C. S. Vol., VII, Part I, p. 107.

Second. When part of the RO is supplied from lime a decided increase in stoniness and toughness is noted.

Third. With a given RO content every increase in clay, within the limits of this experiment, contributes to the fineness of structure and degree of vitrification.

Fourth. The high clay bodies are in every case more brittle than the corresponding numbers with lower clay. There is, however, one exception to this statement, namely, No. 40-1, which shows a loss of 4.6%, while No. 50-1 shows only 3.4% loss.

So far as the writer is aware, no one has ever published the results of research on this phase of porcelain manufacture, so that a direct comparison of the data here presented with the work of other experimentors cannot be made.

A NOTE ON THE MEASUREMENT OF PLASTICITY AND TENSILE STRENGTH.

BY

EDWARD C. STOVER AND JACOB LINDLEY, Trenton, N. J.

Plasticity.

Every potter knows the importance of plasticity, but how to accurately measure and express it in comprehensible and comparable terms, this important condition has puzzled the ceramist. It has been with the hope of filling this want that a line of experiments was undertaken along the lines already proposed by Bischof, for testing clays.

The apparatus used is quite simple, consisting of a hollow brass tube 2″ in diameter and 12″ long, being made conical, at one end, where it is provided with a screw cap ⅞″ in diameter, into which brass collars with various sized holes can be readily secured. A ⅛″ diameter hole has proven most satisfactory in testing plain ball clays and kaolin. The straight cylindrical portion of the tube is provided with a snug fitting brass plunger and rod, the whole being supported by a block with a hole in it, so that it is held firmly in an upright position, when weight is applied to a lever which is attached to the plunger rod.

The clay to be tested is wedged to proper consistency for pressing, and then made into a roll and placed into the brass cylinder beneath the plunger and rod. Weights are then applied until the plastic clay squeezes very slowly through the ⅛″ opening in the bottom disc. The cord of clay thus hangs down, and continually increases in quantity and weight until the piece, by its own weight, pulls loose and drops. The more plastic the sample is the more weight is required to break the cord, and the average of ten results, expressed in grams, seems to form quite an accurate way of estimating plasticity in comparable form, as follows:

American china clay	1.75 grams.
English china clay	2.59 grams.
Another English china clay...	6.11 grams.
American ball clay	14.68 grams.
English ball clay	33.15 grams.
A blue stoneware clay	40.54 grams.

The trials for each clay check quite well. The last one is the average of twelve tests, which ran as follows:

40.0 grams	39.5 grams	40.5 grams
40.5 grams	42.0 grams	42.0 grams
41.0 grams	40.5 grams	41.0 grams
40.0 grams	40.5 grams	39.0 grams.

The above order of plasticity confirms my practical experience with these clays, but before making these tests I had no means of determining to what extent they differed.

Owing to the limited amount of time, I have been unable to complete further tests.

Should a Committee on Standards be appointed, we would be glad to carry on further experiments that may be suggested, and it is to be hoped that others will try this system of tests.

Tensile Strength.

The strength of air-dried clays, and particularly of body mixtures, is quite important, as frequently upon this qualification will depend the usefulness of a material or a mixture for making large or complicated pieces; it is therefore desirable to have a quick and accurate method of measuring tensile strain.

The straight pulling briquette method usually employed for making tensile strength tests is so unlike the actual strains that occur in all ceramic bodies, and requires quite an expensive outfit for properly preparing and breaking the briquettes, that I have tried to simplify a method for accurately measuring cross strains, which are the ones we have to deal with almost exclusively in ceramic work.

Fig. 1. Apparatus for Measuring Plasticity.

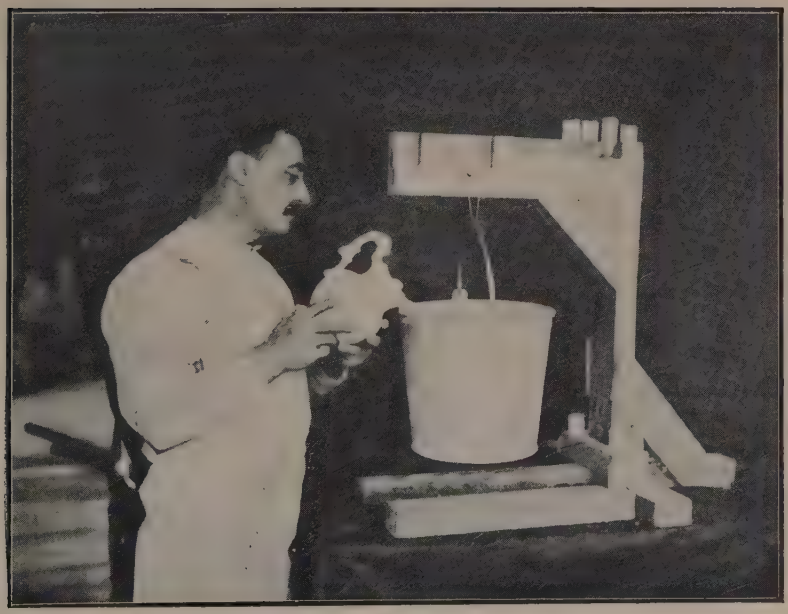


Fig. 2. Apparatus for Cross-breaking Test.

I realize that cross strain measurement is not altogether new. The late Henry Faija, an English Portland cement chemist, devised a machine for measuring transverse strain cement bars, and F. M. Meyer, a German cement expert, also built a similar machine, but both of these are more complicated and expensive than would be required for quite accurate work in clay working.

The accompanying photograph shows a very simple device that any potter could build for himself. By means of a two-part plaster mould clay cylinders 1 3-16″ in diameter, or approximately one square inch in area, drying shrinkage being allowed for, and 3″ long, can be readily pressed as a plastic piece of ware is actually pressed, and by taking the required number of pounds to thus break these cylinders, (average of 10), quite accurate results can be obtained. One end of the cylinder is inserted in the 1¼″ round hole of the upper arm, and placed in the semicircular groove of the fulcrum, shown on the arm or support.

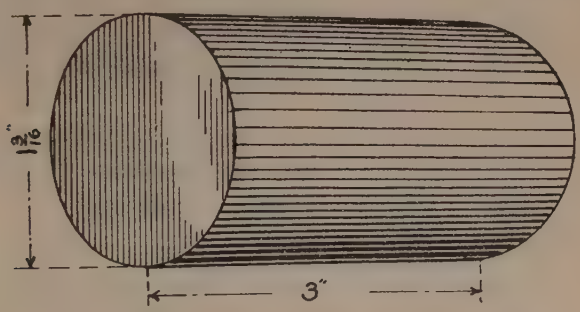


Fig. 3. Test piece for Cross Breaking Strength.

By simply adding water to a bucket until the cylinder breaks, the weight of water and bucket will give the tensile strength. Round sections of one square inch are better than square sections as made by the cement experts, since the square corners are much more liable to cause checking and cracking of th test pieces in drying than the cylindrical pieces, which will give a much higher percentage of perfect pieces, free from cracks.

The results of some tests made by the above described method are as follows:

American china clay, average of 4 samples,
11.85 lbs. per sq. inch.

English china clay, average of 4 samples,
8.81 lbs. per sq. inch.

Another English china clay, average of 4 samples,
12.19 lbs. per sq. inch.

American plastic stoneware clay, average of 3 trials,
42.09 lbs. per sq. inch.

American ball clay, average of 5 trials,
38.40 lbs. per sq. inch.

None of the above results are considered accurate, owing to the fact that the trials were knocked off of a board and fell to the floor while drying, and in one or two cases small cracks, from ¼ to ½″, were developed at the point of fracture that did not show on the surface, since all pieces that showed a crack on the surface were rejected and not tested.

DISCUSSION.

Mr. Binns: I will ask Mr. Stover the brands of American china clay used.

Mr. Stover: I can't give you that information. I think the one shown to be quite plastic was Florida clay.

Mr. Binns: And the American ball clay?

Mr. Stover: I do not know.

Mr. Binns: Do you know what precautions were taken to press these cylinders solid in the moulds?

Mr. Stover: Yes; the pieces were wedged thoroughly and then put into the cylinder and pressure applied until quite a quantity was squeezed out.

Mr. Parmelee: I will ask Mr. Stover what was the percentage of error in the individual pieces. I believe it was an average of twelve that was given.

Mr. Stover: The average of twelve trials of the blue stoneware clay was taken, which I read off. Some were as far off as two units.

Mr. Parmelee: Of course this is not entirely new, but it has the virtue of being very simple, and I am very much in favor of the suggestion in regard to a Committee on Standards.

Mr. Wheeler: That cross-breaking test I hope will be taken up further. It has the suggestion of simplicity and ease of application, and I think it is well worth following up, with more refinement and care on a greater variety of clays. The amount of material used there does not cover a very wide range, and as far as I can see we are getting into deeper water than ever before if we attempt to compare one of these methods with the other. Taking the plunger system, excluding the thread of clay, will commend itself to anyone, and I think it is the best and most natural method to arrive at the plasticity of clay; but unfortunately the means of getting reliable comparative results involves so much care, that we will be compelled reluctantly to abandon it. I realize it will give more accurate results than anything I know of, but it requires great care.

COST KEEPING IN A SEWER PIPE FACTORY.

BY

WILLIAM H. GORSLINE, Rochester, N. Y.

Mr. Mayer, in his valuable contribution on "The Distribution of Cost in the Manufacture of White Ware," has set a precedent which is difficult to equal. Like him, I do not claim to suggest anything perfect. Unlike him, I am not attempting to prove the correctness of a standard price list.

The value of cost keeping to the works manager is so great, that it is surprising that proper methods have gained so little foothold in the clay working industries. The contrast between the latter and the highly developed system in most machine shops is very marked.

As in some other industries, cost keeping in a clay working establishment cannot settle finally in every case, the question of profit in producing certain articles compared with others; for the total cost, chargeable, cannot be analyzed as closely as desirable, without undue expense. For example: In producing large sizes of sewer pipe, more power is consumed and so more steam coal is burned than in the production of smaller sizes. In other words, a less number of mills will keep a press going on 3″ pipe than on 24″ pipe.

Leaving these refinements out of the question, I will attempt to describe a method employed in the manufacture of sewer pipe, the general principles of which might be adapted to other branches of clay working.

A principle laid down, is to divide up the process of manufacture into its various elements as far as possible. Hence, on the foreman's reports, which form the starting point, care should be given to the making of the divisions.

A form that has been used is the one marked "A." The items that do not go under printed headings are added at bottom of form. From this a boy can compute the labor charges, and distribute them in an auxiliary book. The records thus established, although still incomplete, are valuable for reference when considering a proposed labor saving method, or a re-distribution of men in the different operations. If one cares to experiment, those figures will show whether the shop cost is increased or reduced in any

A.

FOREMAN'S DAILY REPORT.

Hours		Production	Pieces	Mill	Labor		
From	To	Sizes			Press	Floor	
7½	6	4 in. Pipe	4000	4	6	3	

Hours		No. of Men	Sizes	Pieces	WORK
7	8	2	18″ Rings		Moving
7	8½	3	24″		Boards
8	9	2	24″		Boards
9	6	5	18″ Pipe	1500	Taking down
7	7½	2			Changing die 5″—4″
7	7½	4			Wheeling grog
7	7½	1			Cleaning up
7	7½	9	10″		Boards
7	3	1			Crusher
3	6	1			Wheeling grog

(Signed)_____Foreman

size by using more or less men for any particular operation.

After having obtained the labor charges, the cost of material is the next consideration. It is impractical in the production of red burning wares, to weigh the raw clay as used; there is too much to go back on account of cuttings and waste. But it is quite easy to determine accurately the loss in weight from the raw clay before being tempered, to the finished product. Hence, the percentage of loss added to the known weights of the finished product, will give the weight of the raw clay used, which is the weight at which the original cost of the clay is figured. It is then easy enough to determine the cost of clay used for each run.

Now we have shop labor cost and clay cost. Next must be determined the burning cost, which is a more difficult matter. I quite agree with Mr. Mayer that averages are misleading, unless they cover a sufficiently long period of time. The average list per kiln for the year previous has therefore been taken as a basis. Then is figured the percentage of burning cost to the list.

Chargeable to burning cost is:

1. Labor of setting and drawing kilns.
2. Burners and helpers.
3. Salt.
4. Sand.
5. Coal.

In order to dispose of the sand not used in the mixture, it is all charged to burning.

These items, which comprise the burning charges, are treated as follows: The total for the salt, sand and coal expenses for the previous year is divided by the number of kilns drawn during that year. To this result is added the total labor charges per kiln, as given above. See "D." With this result, and the average list per kiln for the year previous, the percentage of the burning cost to the list is obtainable.

O=total of salt, sand and coal forming the burning charge for previous year.

N=Number of kilns drawn during previous year.
L=Total labor charged to one kiln of ware.
A=Average kiln list for previous year.

$$\frac{\frac{O+L}{N}}{A} = \% \text{ of burning to list.}$$

The unproductive factory labor per hour and fraction thereof is charged to each run of each size.

If it is desired to obtain the yard charges, (labor), they must be obtained during the previous year through a report system similar to form "B." This may then be

B.

ROCHESTER SEWER PIPE COMPANY

DAILY YARD REPORT

Date.....

Signed .....*Foreman*

Time		Car and City Deliveries	Coal	Clay	Yard	
From	To					

added to the total of the horse and wagon and lumber accounts for the previous year, and the grand total can be treated in either of two ways:

First. The percentage of it to the list of production for the previous year, can be obtained and used, or

Second. This grand total may be divided by the number of kilns drawn during the year, and it can then be added in with the items that go in under burning cost.

Periodically a statement should be made, showing the average cost per ton on each size. Any variation in the cost per ton in the different sizes would disclose a loss or gain in labor expense.

The fixed charges of the previous year, so aptly termed by Mr. Mayer as "dead" expenses, can be charged up per hour, or as a percentage of the list produced.

On account of variations difficult to trace, averages have been used as seen, except in labor and clay charges, and recourse to the previous year's records has been necessary. This would be misleading in some years, if works repairs are not properly attended to annually . But if this is done, a depreciation account is therefore avoided, as the expense for proper maintenance of plant and machinery should offset depreciation.

The imperfections of the foregoing are keenly realized, and it has been given for the benefit of the discussion it is hoped it will arouse.

E.

Size _____

Dates, _____ Hrs., _____ Pcs., _____

Lbs. Raw, _____

Labor, _____

Clay, _____

Unproductive, _____

Coal and Burning, _____

Kiln and Boiler, _____

Total per Pc., _____

Total per Cwt., _____

Per cent. Cost to List, _____

The above has been employed by me for one year, using a card "E" for one or more runs of the same size. The data furnished has been formulated, and this method is not employed regularly now. When changes of any kind occur, I refer to it as a basis for calculation. I now use another method, taking everything as it comes. See "G." This is based on report forms "A" and "B." To G are added special divisions as desired when making repairs on new installations of which the total labor charges are desired.

G.

LABOR EXPENSE DISTRIBUTION.
DAILY TOTALS.

	Daily totals 1st		2nd			Total for Month	
Fire brick unloading.							
Coal-Boiler							
Coal-Kiln							
Clay No. 1-unloading							
Clay No. 2-unloading							
Clay No. 3-unloading							
Clay bed							
General							
Kilns							
Lumber-unloading							
Pit clay No. 1							
2							
3							
Repairs-General							
Kilns							
Salt-Unloading							
Sand-Unloading							
Sewer Pipe Production							
Sewer Pipe Grog							
Terra Cotta Production							
Terra Cotta Grog							
Yard-Car Loading							
Inside							
Outside							

This leads to a healthy scrutinizing of the different expenses of the business, and together with expenses for material, would show total cost of operating. Then by keeping kiln and press weights, the cost per ton could be obtained, "H," which could be compared to the standard price list to good advantage. See "K." This, and the percentage of each of the sundry expenses to the total cost, or to the total list produced, would supply the works manager with information that should be of valuable assistance in helping him to form his policy.

H.

Dates	Press Production			Kiln Production			
	List		Weight	List		Weight	

K.

Sizes	Labor	% to List	Clay	% to List	Unpro-ductive	% to List	Burning	% to List	

Arbitrary Burning Percentage.

On basis of——kilns per——

	Kiln day cost
..... Burners @ —— per day =	.....
..... Helpers " —— " " =	.....
$\frac{\text{..... tons coal used}}{\text{..... Kilns drawn}}$ per year x cost per ton =	.....
$\frac{\text{..... tons salt used per year}}{\text{..... Kilns drawn per year}}$ x cost per ton =	.....
$\frac{\text{..... tons fire sand used per year}}{\text{..... Kilns drawn per year}}$ x cost per ton =	.....
Labor cost drawing and setting per day =	.....
Total kiln cost per day =	

$\frac{\text{Total kiln cost per day}}{\text{Average kiln list}}$ = Burning cost per centage of list

MEASUREMENT OF SETTLE IN BRICK KILNS.

BY

L. E. Barringer, Schenectady, N. Y.

The description of apparatus indicating the loss of water in clay wares under fire, given by Mr. Gorsline in Vol. V of the Transactions of the American Ceramic Society, brings to mind a device constructed by the writer in 1900 for the purpose of indicating the settle in brick kilns. The wares burned were dry-pressed bricks of different colors and shapes, buff, gray, terra-cotta and red in Standard, Norman and Roman. These were burned both in Guthrie continuous kilns and in Eudaly, Stewart and other types of periodic kilns. It was the practice in operating the continuous kilns to gauge the finish of a chamber by the settle of the brick, this being measured by the fireman from the top of the kiln in the following manner:

After the setting of a chamber was completed and everything made ready to water-smoke, a long iron rod was let down through the center firing hole in the crown of the chamber, until it rested on the top course of bricks. Keeping the rod as nearly vertical as possible, a chalk mark was made upon it where it crossed the iron rim of the hole, thus showing the distance from the crown to the top course of bricks. This rod was then hung nearby and used during the burning off of the chamber, noting at frequent intervals the position of the original chalk mark and showing the settle of the bricks. The settle was measured only every 24 hours during water-smoking, which was accomplished by a fire in the wicket and occupied 8 to 10 days.

After the chamber had been connected and the heat from the chamber in the rear admitted the real settle began, and measurements were made every three hours until the end.

In using this method it becomes very difficult to make close measurements when the kiln is at high heat, as one cannot work comfortably so close to a white-hot fire as the fire-hole of the kiln. Keeping the measurements on a number of chambers involves time, which it occurred to the writer could be saved and would enable firemen to wheel their own coal and save the labor of a coal-wheeler. This method of using a rod and measuring from the crown necessarily gives readings which include the rise of the crown, and the real settle is not indicated, but the apparent settle. Of course, for comparative purposes this is not objectionable as long as the crown swells approximately the same each time, which is usually the case, and the same hole is used from which to measure. If, however, rolling in the kiln or any other irregularity makes it necessary to measure from the side holes, the apparent settle is notably less than from the center hole, due to the falling off of the amount of crown-swell as the ends of the arch are approached.

In experimenting with means of registering this settle mechanically, the apparatus here mentioned was found to be convenient, accurate and regular. A fire-clay rod long enough to reach from the top course of bricks to within a foot of the crown, was attached by wire to a dial placed on the roof framework. A hand on the dial indicated on a calibrated scale the movements of the fire-clay rod in the kiln beneath. A short section of platinum wire was used from the rod until the surface of the crown was reached, from whence thin copper wire was used to the dial hand. The arrangement is shown in the attached sketch (Fig. 1). A fire-clay slab may be used for a convenient rest for the fire-clay rod. The dial is made of wood and is easily calibrated, and the divisions painted or simply inked on. The amount of circumferential distance traversed by the pointer for each inch of linear motion of the rod is gauged by adjustment of the dial pointer. Making the ratio of mo : no greater increases the spacing on the dial corresponding to the linear distance traversed. Divisions of 1-16

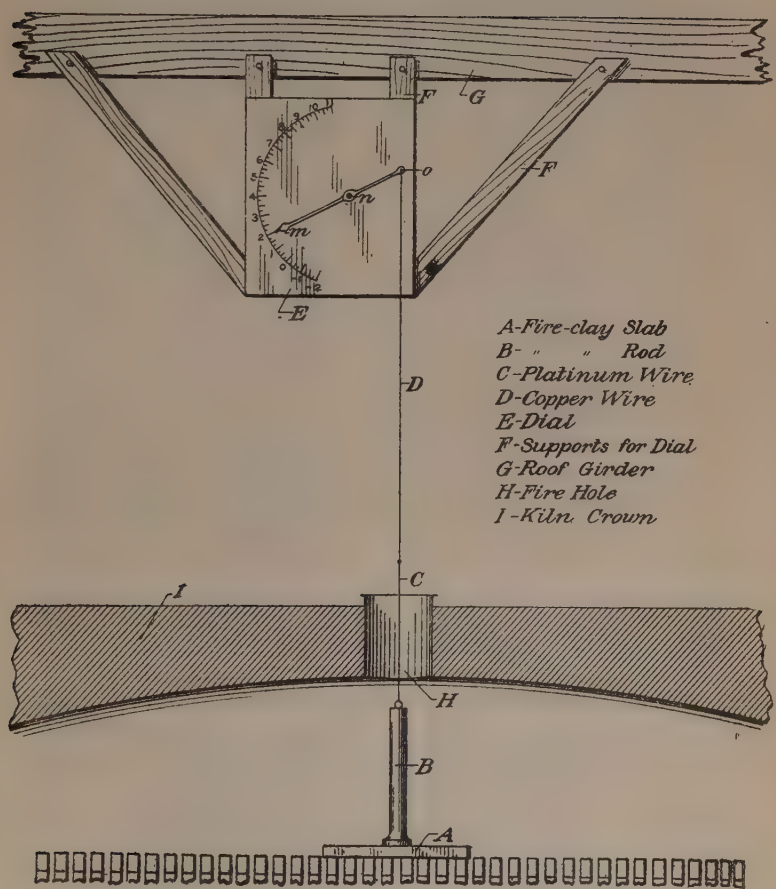


Fig. 1. Apparatus Recording Kiln Settle Mechanically.

inch are easily made to be read at a distance of several feet. The whole apparatus is decidedly cheap and simple.

A dial for each chamber or kiln may be used, or only several dials, transferring them from one place to another and merely hanging up on nails provided for the purpose.

The results of the readings were plotted on co-ordinate paper kept on a bulletin board nearby for the purpose. By going the round of these boards and observing the settle curves, the foreman could keep close track of the condition of his entire kiln.

In Fig. 2 are shown two curves obtained from the same kiln, one by rod in the usual way and the other by dial. It will be noticed that by dial the settle is always less than by rod, and this difference is approximately the amount of crown expansion which is included in rod measurements. The curves closely parallel each other. Where they cross is very nearly the point where the crown expansion begins to be a factor.

In Fig. 3 are shown curves of settle by rod and dial, curve of crown expansion and curve of differences in dial and rod measure. Crown expansion was measured by simply placing a brick on the top of the crown and connecting this with the dial. As the crown rose the dial hand gave negative readings, indicating the amount of swell. Leaving on the dial after the chamber was burned off, the dial indicating crown-swell, again read zero after the kiln was cool, usually a very short time after the wicket was taken down. Theoretically, the curves of crown-swell and differences in rod and dial should be the same. It will be noticed that they closely approached each other. Differences of rod measure by different firemen, and the inexactness of rod measure, are undoubtedly largely responsible for the distance between the curves.

In all the curves, after the first settle occasioned by drying out free water, a rise in the curve is noticed. This I have attributed to expansion by heat during the interval when nearly all free water had been driven out and before the expulsion of combined water had commenced.

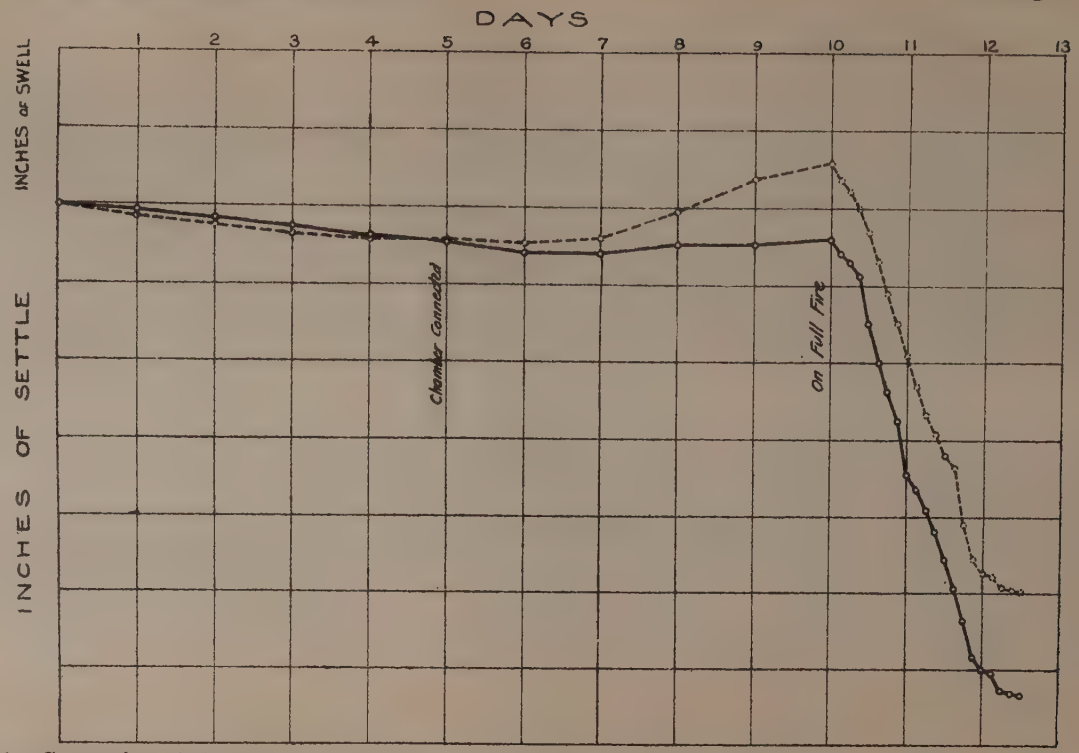


Fig. 2. Comparison between rod, hand measure and mechanical dial measurement of settle. Dotted line is dial measure, solid line, rod measure. Records from Guthrie Kiln, 22 bricks high.

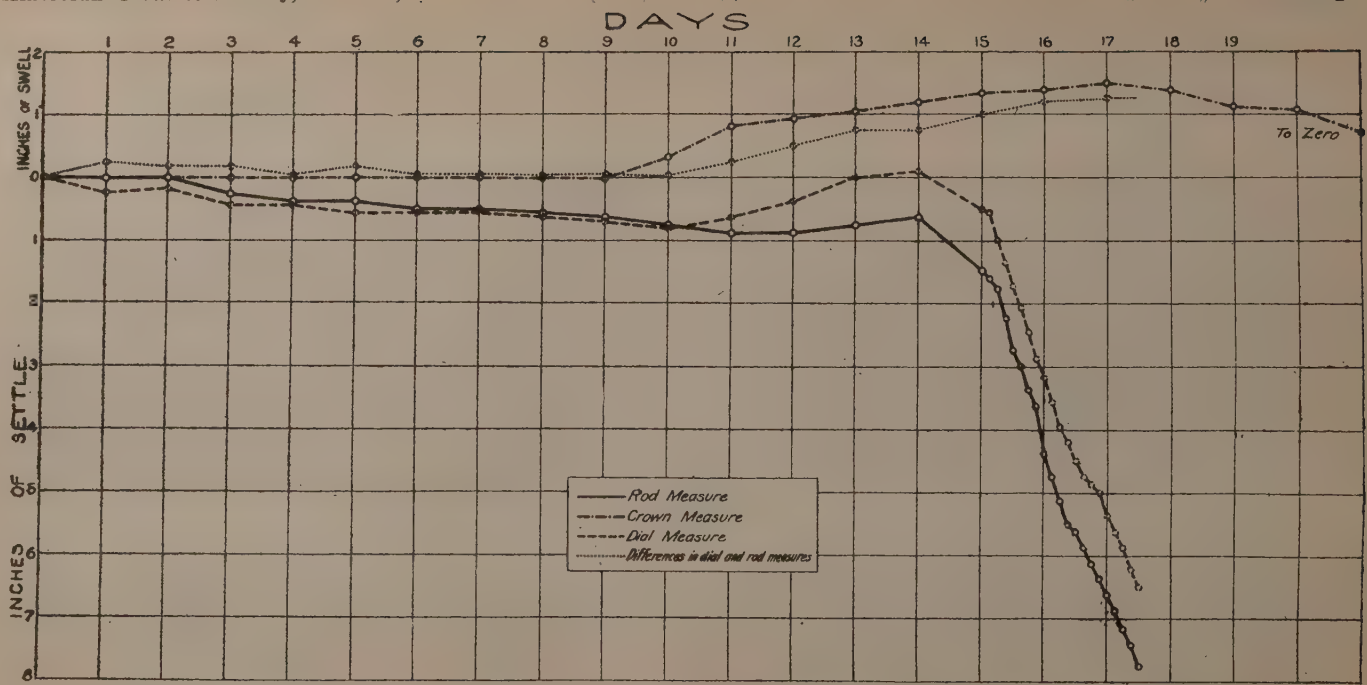


Fig. 3. Curves showing differences between dial and rod measurements. Records from Guthrie Kiln, bricks set 22 courses high.

DISCUSSION.

Mr. Yates: I will ask the gentleman whether he considers the indicator reliable, if he is sure the kiln is going all right if he follows it carefully?

Mr. Barringer: I do not see why not. The only thing which could happen would be for the rod to break, and you could see that. Of course such things are apt to happen.

Mr. Yates: Suppose he starts his settle too quick, what assurance has he that the kiln is settling in the bottom? Have you any means to show where the settle takes place?

Mr. Barringer: You can take the rod and slip it down in the kiln and measure by hand.

Mr. Yates: I should not think that would be reliable. I assume if a man using this indicator gets heat in the bottom, and if he crowded his fires too fast the settle would be in the bottom, and it would not show. The settle should be given for the bottom as well as the top. If a man simply watches this instrument, he will not know whether his settle is in the top or bottom.

Mr. Barringer: We do not follow this blindly; the burner watches his fires also.

Mr. Binns: Mr. Yates is arguing against firing by settle at all. If firing is done by settle at all, this is certainly an improvement over the old method. I will ask Mr. Barringer what he depends on to draw the finger, the platinum wire attached to the fire clay slab. Is there any weight on the finger to resist the pressure?

Mr. Barringer: No counterbalance is used.

Mr. Binns: What keeps it horizontal?

Mr. Barringer: This rod (indicating) is solid enough to stand right down on the brick.

President Gates: If the wire would break, is there weight enough in the hand to indicate by itself?

Mr. Barringer: If the wire would break, the needle would drop back.

on board). That was the kind of firing we were getting up

Mr. Orton: I would like Mr. Barringer or Mr. Lovejoy to explain how they use the data from this in keeping records on the different chambers? This method of measuring settle in the kiln, as shown by Mr. Barringer, is used in your plant, is it not, Mr. Lovejoy? You use it by keeping a curve of the settle in each chamber?

Mr. Lovejoy: Yes, sir.

Mr. Orton: Couldn't one of you gentlemen bring out the point as to just how it is used, how the men keep the information and the effect of it?

Mr. Lovejoy: The dial arrangement Mr. Barringer has described to you was adopted more to determine the point of rise in the crown. It was always measured as follows: We had cast iron caps with small holes. We ran a rod through them down to the brick and made the mark on the rod. We took cross-section paper and marked here (indicating) the inches. It was ruled in eighths both ways. This (indicating) represents the inches, whatever the settle is, and each eighth of an inch, this other way represents the hours, except out at this point (indicating) where it represents days. Each day at noon we would measure the settle and put a cross on the point, wherever it was, on the cross section paper. The dial which Mr. Barringer got up was to get at the rise and fall of the crown. There is always a swell in the brick just at the stage when the combined water is going off. That point used to be very irregular. Sometimes the brick would go back until higher than the original height shown on the rod, or in other cases it would not show any rise at all. When we tried it with the dial we found that it invariably swelled until it was higher than the original height of the brick. At this point, when it began to swell, just about the time it reached the top, we changed the measuring from once a day to once every three hours, and continued to put down the marks on paper. We adopted it more as a check on the fireman. We found the firing was very irregular, and when we first adopted the plan we got all sorts of curves (illustrating

to the time we adopted this system, using cross-section paper. Since then ninety percent. of the curves will be fine. As a graphic illustration of the settle and a check on the fireman, it worked out beautifully and the work improved. In firing, if the man found his curve was going across here (indicating), and if the next came out there, he would know he was firing too slow and would fire faster, and thus it gave a check every three hours on the amount of fuel used. In that way we got very regular curves and uniform work. The results have been very beneficial to the factory. As I remarked in the beginning, this dial arrangement of Mr. Barringer's was adopted to get the swell of the crown.

Mr. Orton: Possibly you can furnish two or three curves which would show the typical changes during a fire, for printing in our transactions? Do you think you can get them?

Mr. Lovejoy: No doubt I can get any number of curves from the factory, not only on continuous kilns, but on downdraft kilns as well. Take a downdraft kiln, fifty or sixty feet long, and measure in three or four places, and it serves as a guide to determine the character of the firing at the different places, whether the firing is light or heavy. To determine the heat in the center, to locate hot spots, is a difficult matter, and it is impossible to determine it by cones. Cones are useful within five or six feet, but when you come to forty feet in a kiln, there is nothing to measure the variations. As far as I know there is no way of reaching the center of a body of brick ten or twelve feet high and fifty or sixty feet long, except by this method of settle. I have no doubt I can get from the factory curves showing this method of measurement on this kind of a kiln and on a continuous kiln.

Mr. Orton: It would add greatly to the value of our Transactions in this connection, it seems to me.

Mr. Gorsline, didn't you have some experience along this line?

Mr. Gorsline: My apparatus is slightly similar to that, though we used a beam somewhat like a chemical balance. On one end of the horizontal balance, inside the kiln, we suspended a piece of clay, which as the water left the clay would show the loss of water by raising that end, and by the addition of weights, the equilibrium could be restored and a curve could be plotted showing loss in weight. But I should think this method would be much better in a brick kiln.

Mr. Orton: You never applied your balance to the determination of the settle?

Mr. Gorsline: No, sir. I was thinking we might use this method in a sewer pipe kiln to determine the settle; but it would be very inconsiderable as compared to the settle in brick, and of not so much value.

Mr. Stover: Are these clay pieces previously fired?

Mr. Gorsline: No; they are of the same dryness and in the same condition as the clay in the kiln being burned, so that the loss in weight is the same as in the ware being burned. Our measurements would be the measure of the loss in weight due to loss of water and organic matter. These pieces are suspended and just the difference in weight noted. Mr. Barringer measures the settle and I measure the loss in weight.

Mr. Stover: Are the pieces you use green pieces, Mr. Barringer?

Mr. Barringer: They were always fired pieces and the rod hard fired, so that there would be no shrinkage.

Mr. Hull: I do not quite understand Mr. Gorsline's statement, that the settle would be much less in a kiln of sewer pipe than in brick.

Mr. Gorsline: I made that statement off-hand. I should think, there being less clay in the bottom of the kiln, at the place where the settle is measured, that there would be less opportunity for shrinkage and settle.

Mr. Lovejoy: How many inches of settle do you get in common sewer pipe?

Mr. Gorsline: I never measured the settle, but the shrinkage is one in eight.

Member: You get a foot of settle in eight, which is more than the settle in a brick kiln.

Mr. Gorsline: Yes; then it would be of a good deal of value to sewer pipe men.

Mr. Yates: This seems rather a risky system. If it were rearranged with three wires, one ten courses from the bottom, another in the center and then another on top, so you could get the conditions in each place, it would be valuable. But you have the indicator for the fireman to follow, regardless of where the settle is.

Mr. Lovejoy: It may be a risky system, but the company which adopted it never missed a dividend since it was adopted.

Mr. Burt: Mr. Lovejoy speaks of the difficulty in getting the exact heat, but it would be of the greatest interest if we could know just the point in that shrinkage at which the swell came in, the point of heat. As you cannot get at the exact heat by pyrometers or cones, cannot you give us an idea as to whether it is a red heat, a cherry red, or before that?

Mr. Lovejoy: I cannot give you that now from memory, but I think I can find the facts in regard to it. Quite a number of years ago we wanted to determine the point at which the combined water was driven off. We took a series of bricks, drilled holes in them and filled the holes with various metals, melting at different temperatures. Every several hours these were taken out, weighed and measured. My recollection is that the point at which the combined water was driven off was somewhere between eight and nine hundred degrees by that test. The facts were all published at the time in The Clayworker, and subsequently copied from that into one of the geological journals by Professor Ries. In one or the other of these

journals you can get exactly the point you wish to know. It can be secured and incorporated in this paper. It was at a low red heat.

Mr. Stover: If I remember right that point was covered by Professor Orton in his Boston paper But would not the point be affected by the nature of the mixture—whether using an all-clay body or clay with a percentage of grog. Would not the time differ somewhat with the mixture?

Mr. Orton: I stated in my paper that the temperature at which the combined water began to be expelled was about 550°C, and it ran up to 750°. I do not know whether I stated it there or not, but I can state that I do not think it makes any particular difference as to the amount of grog. It would make a difference as to the rate at which it would come off, but not much in the temperature. We have had occasion to make curves on the loss of water, dehydration, several times. I give it as an exercise to the students once a year. We have always found on the pyrometer which we have been using, which has been standardized several times, that the losses began at about 550°, perhaps a little earlier, but they do not become important until 550°, and they decrease down to about 700°C.

President Gates: Do not you think that a clay burning at a low heat would vary in the point of giving off its water from a high-burning clay?

Mr. Orton: I do not think so, Mr. President. The water which comes off is a part of the mineral kaolinite. If it is the same mineral throughout all the different clays, it should break up at about the same temperature conditions. Fluxing appears very much later.

Mr. Gorsline: A clay vitrifying between cones three and four will average up to redness a loss of 10 grams per hour, and from redness to bright red heat it will give an average loss, per hour, of 28 grams, showing a greater loss after redness than before.

President Gates: This is certainly a very interesting discussion. I think it is one of the most valuable things we have had.

Mr. Hull: It occurs to me we are likely to be blaming sewer pipe with more settle than belongs to it, in comparison with brick. I believe Mr. Gorsline's statement of one to eight was total shrinkage, was it not?

Mr. Gorsline: Yes, from the yard to the finished product. Half of the shrinkage occurred in the kiln.

Mr. Hull: In the case of brick it is from the dry to the finished brick.

NOTE ON SETTLE RECORDS.

BY

ELLIS LOVEJOY, Columbus, Ohio.

In the following pages I have collected a series of settling curves from several styles of kilns. The settle is measured every twenty-four hours through the drying and combined water stages, and beginning with the first measure which indicates that the final settle has begun, they are measured every three hours. Only a series of records will show the shape of the curve at the turning point. One kiln may have just started to settle when the three hour measurements began and the curve will be gradual, while the next kiln may have been settling nearly twenty-four hours before the first settle is taken, and the turn would apparently be abrupt. This question was not under discussion, but I selected records illustrating this point.

Two of the drawings show no swell. This is unusual in an ordinary braced kiln, perhaps due to cold weather and extremely tight bands. In the continuous kilns, the one with longitudinal arches braced by retaining walls, usually shows more swell than the one with transverse arches. The reason is obvious. In the former kiln the arches expand laterally, and in the latter kiln the expansion is vertical. The record of the former more nearly represents a true settle than that of the latter.

Barringer's experiments were made on the longitudinal arch kiln. Settles vary with the character of the material, the rapidity of burning, and the desired hardness and color. These facts are always taken into consideration, and also the degree of *swell.*

Other things being equal, the higher the swell, the fewer inches of apparent settle required.

The records also show the speed with which different kilns can be driven to get satisfactory results. Every kiln will have fast and slow burns, but in general the under

fire, solid bottom, kilns are the fastest. A settle of an inch or more every three hours is not considered too fast, and the fires are not checked. In the down draft kilns three-eighths to one-half inch every three hours is counted normal. In the continuous kilns the settle is often as low as one-eighth inch in three hours, continuing so throughout the burn, but this is too slow for satisfactory results, and the burning is driven to get heavier settles as shown in the record, when possible.

Kilns containing large quantities of moulded bricks, or specials of any kind, are fired slower than those containing standards.

Settles in kilns measured at several points are not counted good if the extreme difference is more than one inch at any measuring time, and they are usually well within this difference.

The records shown are average ones, and it will be noted that except in one case, they are so close together that they could not be plotted without confusion. In practice they are plotted on separate sheets. The swell occasionally rises to the starting point, and even passes above it, notwithstanding the expansion of the arch. If we could eliminate this expansion I think the swell would always bring the top of the brick higher than the original level.

Editor's Note:—Mr. W. D. Richardson, of Columbus, Ohio, also read a paper on "Kiln Records" at this meeting at the request of the Secretary. Owing to the fact, however, that Mr. Richardson was compelled to publish the curves in another place he requests that his paper be omitted, as he would not care to ask the Society to print matter which has already been in a publication.

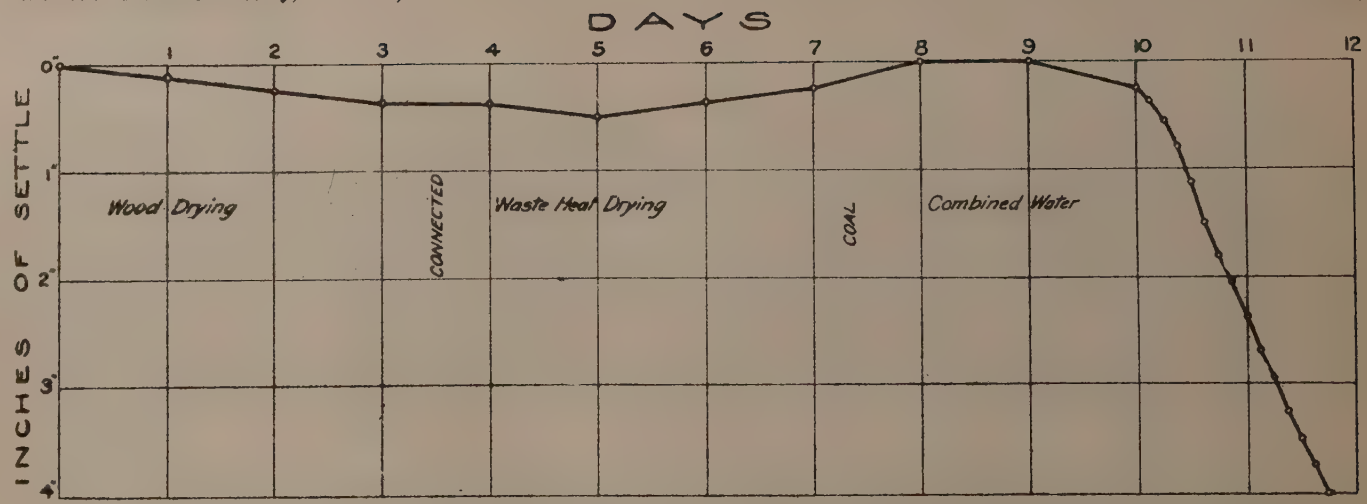


Fig. 1. Continuous kiln record. Set 18 bricks high. Arches parallel to axis of kiln, held by light retaining walls which allow the arches to expand horizontally and the curve, in consequence, approximates the actual settle.

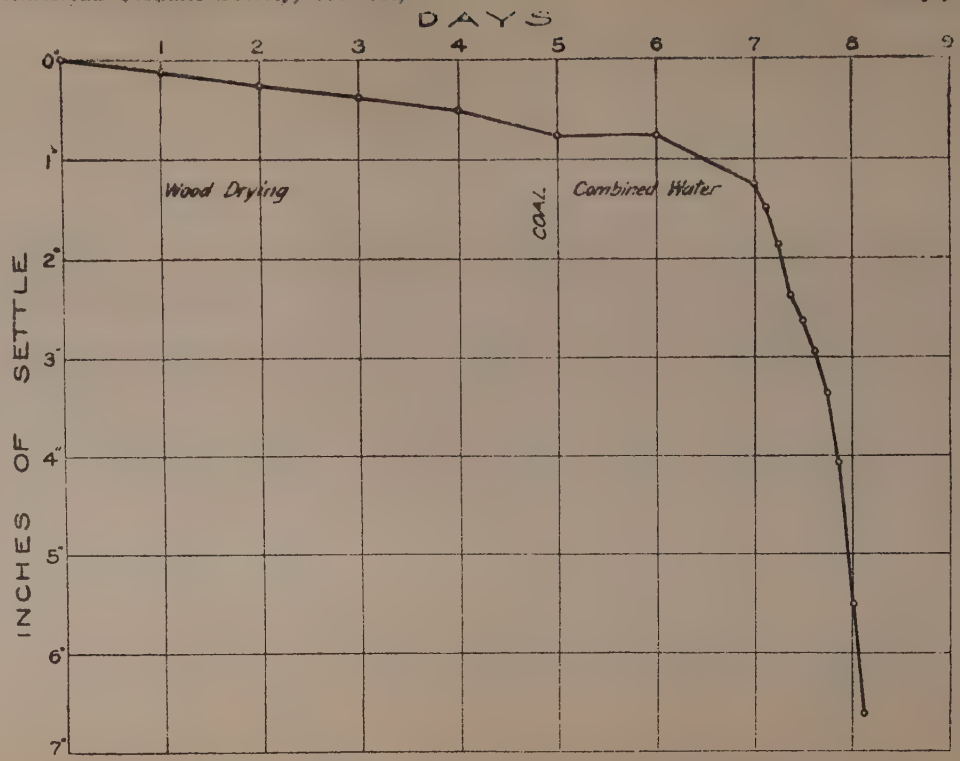


Fig. 2. Record showing pause but no swell in combined water stage.

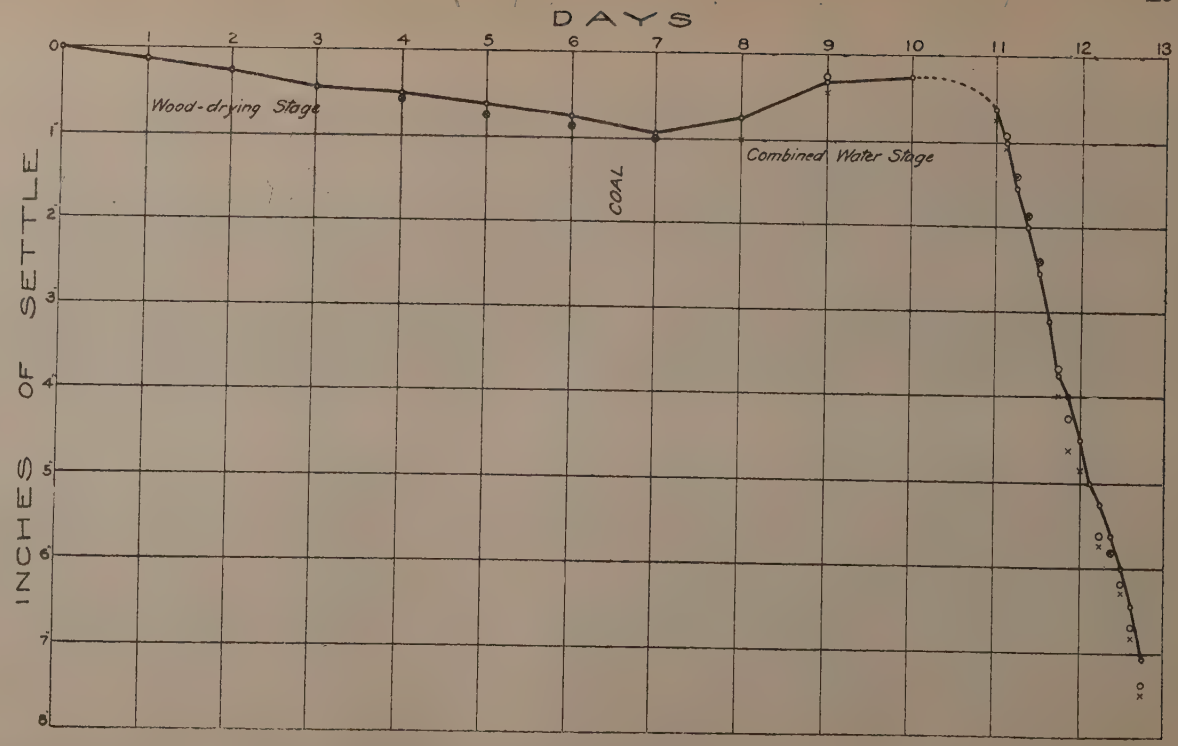


Fig. 3. Record of an 18 by 50 down draft kiln, set 28 bricks high. Curve shows settle at one end of kiln. The x marks show deviation in center of kiln, the o marks deviation at the other end of kiln.

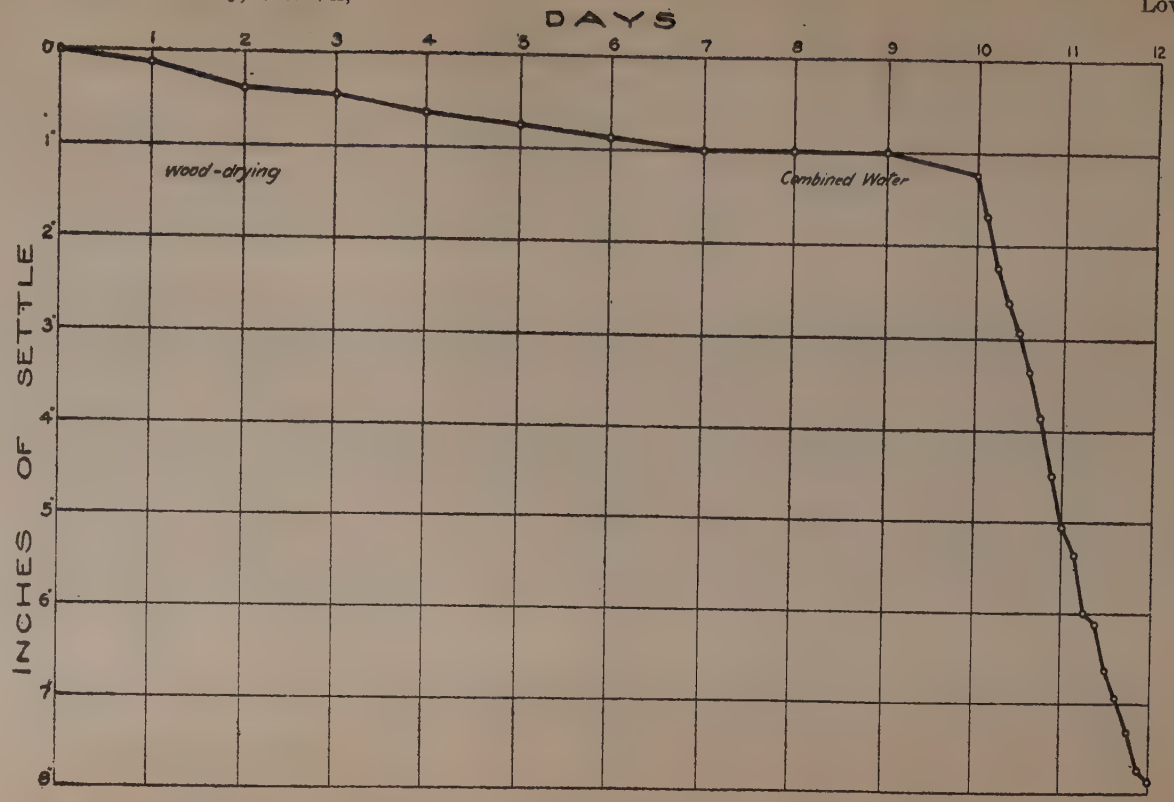


Fig. 4. Record of a round, down draft kiln, showing pause but no swell. Set 28 bricks high.

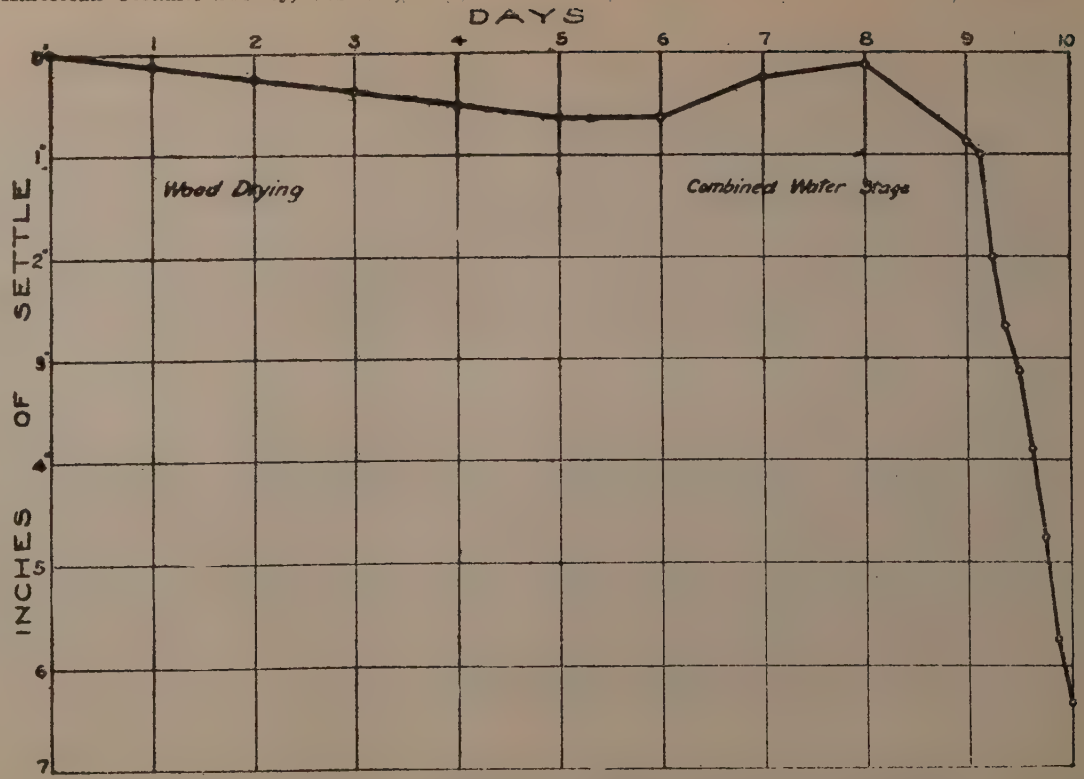


Fig. 5. Round, under-fire, solid floor kiln, see Vol. II, page 50. Set 24 bricks high.

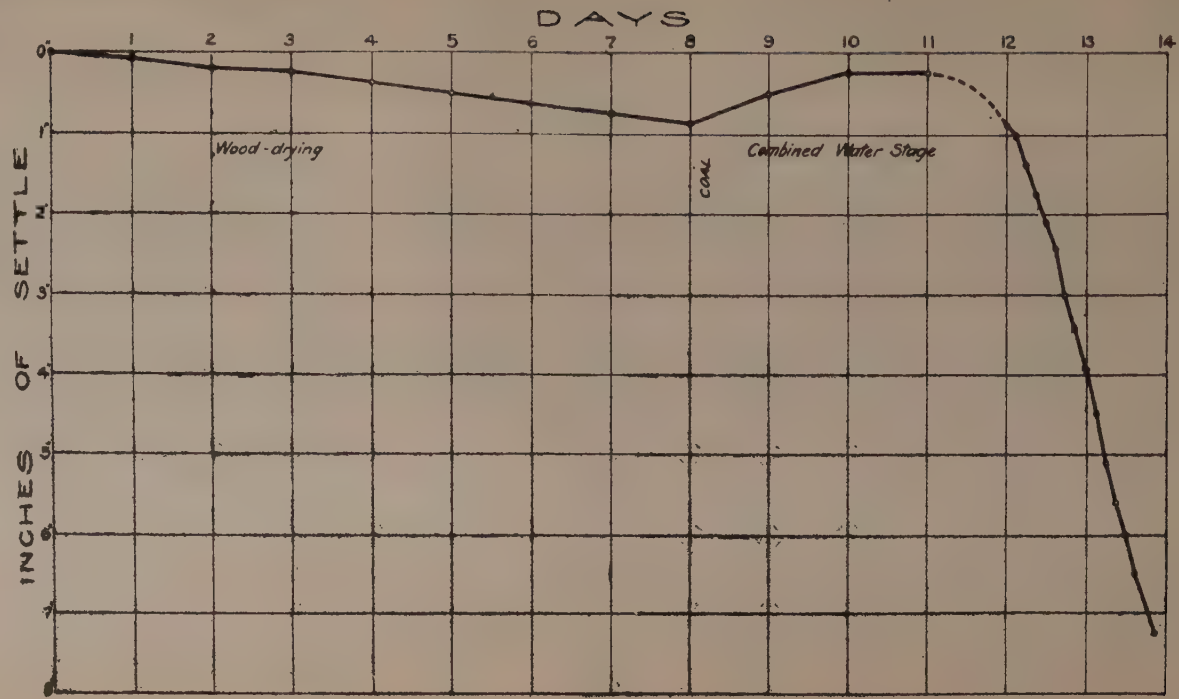


Fig. 6. Record of round down draft kiln, set 28 bricks high.

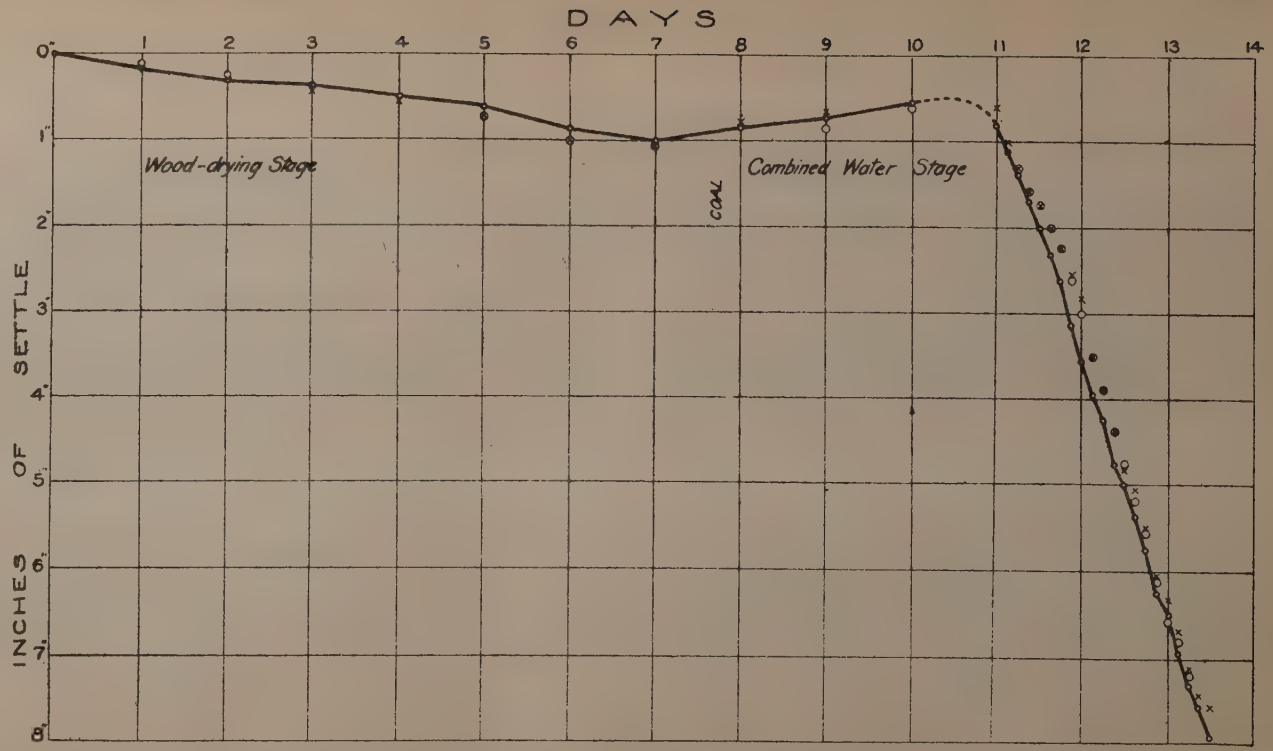


Fig. 7. Record of an 18x58 down draft kiln. The curve shows settle in the center. The x and o marks show deviations at ends.

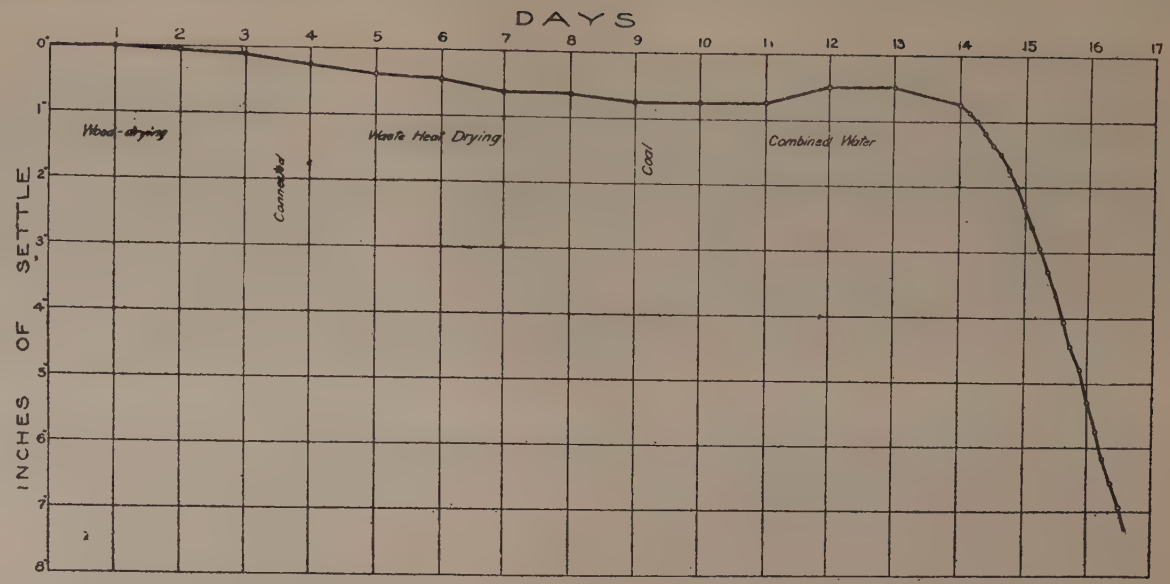


Fig. 8. Continuous kiln record, set 28 bricks high. Swell usually slight because arches of kiln are built heel to heel and expand vertically, offsetting swell of bricks.

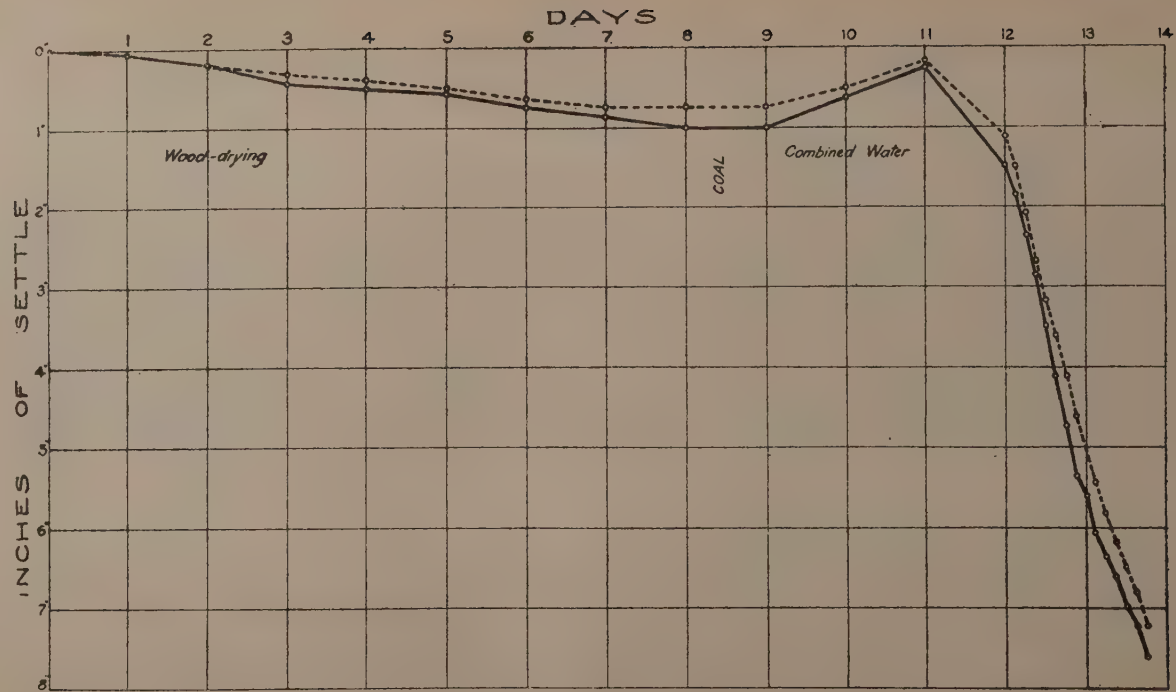


Fig. 9. Record of a 16x20 down draft kiln, set 28 bricks high. Measured at each end.

FIRING RECORD.

KILN No._____ BURNING No._____

	DATE	TIME	HOURS	TOTAL FUEL CONSUMPTION	BOILER FUEL CONSUMPTION	KILN FUEL CONSUMPTION	DRYER	TRIAL KILN	DRAUGHT	PYROMETERS MELTED IN TOP TRIALS					PYROMETERS MELTED IN BOTTOM TRIALS					GAS ANALYSIS				WARE PLACED					
										1	2	3	4	5	1	2	3	4	5	CO_2	O	CO	AIR	FIRST RING	Per Cy. Loss	SECOND RING	Per Cy. Loss	THIRD RING	Per Cy. Loss

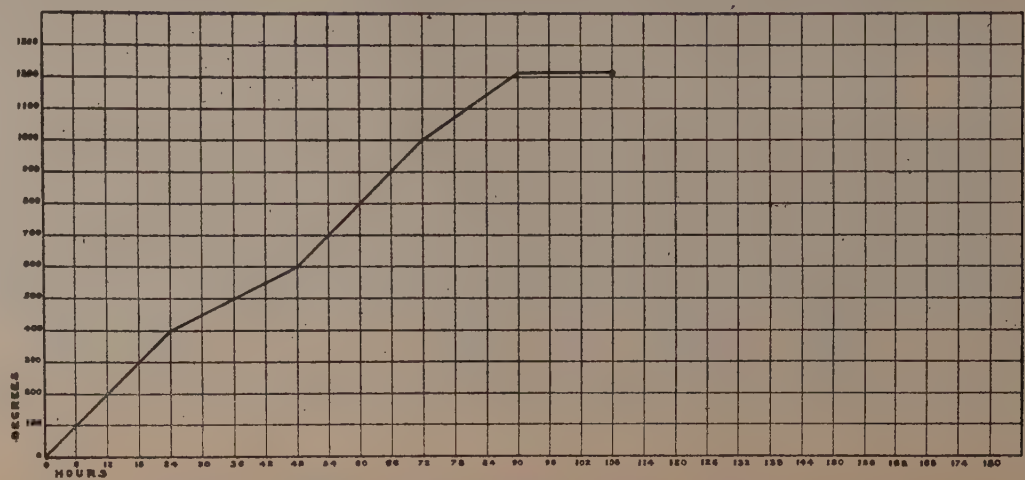


Fig. 10. Kiln record of Mosaic Tile Co., Zanesville, Ohio. Sent in by R. C. Purdy.

DISCUSSION ON "THE HEAT CONDUCTIVITY OF REFRACTORY CLAYS," BY H. A. WHEELER, VOL. VI, T. A. C. S.

BY

E. P. PAGE, Stourbridge, England.

The method employed in testing the relative conductivity was crude. The most important factor to be taken into consideration is the *difference* of temperature on each side of the test pieces, viz: the side heated and the side from which the cooling takes place.

Of course Professor Wheeler relied on the temperature of the heated side being the same in the case of each piece tested. This is not safe to assume; the calorific power of the ordinary gas supply is not so uniform but what a serious error may be caused. Further, the pressure on the gas main varies during the day.

Also, there is no basis of comparison with the results of similar tests made by other people.

The conditions of heat conduction are as follows:

$$H = \frac{A\ T\ K}{C}(T_1 - T_2)$$

Where H = the quantity of heat flowing through in the given time.

A = area of heated surface.

C = the thickness of substance through which heat flows.

K = specific thermal conductivity of substance.

T_1 = temperature of heated surface.

T_2 = temperature of surface cooled.

T = unit of time.

So that if we consider A and T as fixed quantities, H will be increased by a decrease of C, or an increase of K, or $(T_1 - T_2)$.

Or the fact may be stated as follows: From every point of the retort to which heat is applied, there is a flow of heat through the thickness of the retort to the compara-

tively colder surface inside, and the rate of flow is greater the thinner the retort, and the greater its conductivity.

The steady flow of heat continues as long as heat is supplied to the outside surface and an equal quantity removed from the inside.

When these conditions are not fulfilled, the quantity of heat supplied to the outer surface may be greater or less than that removed from the inner surface. In the first case there is an accumulation of heat in the retort and the temperature rises, in the second case the retort is cooled.

Taking the case of a bench of retorts, the furnace being of such capacity and properly proportioned to maintain a temperature inside the retorts sufficiently high for the carbonisation of coal, say 1110°C, the point for consideration is, what is the minimum furnace temperature for a particular make of retort to maintain this temperature of 1110°C inside the retorts. This gives the factor $(T_1—T_2)$, see equation.

The less the difference, $(T_1—T_2)$, for a given thickness, C, the higher is the factor K—and hence economy in fuel, by not having to maintain such a high temperature in the furnace, T_1.

When the retorts receive a fresh charge of coal, the temperature T_2 is lowered considerably, and, assuming that the furnace is working well and at the same temperature at which the previous charge was finished, T_1 is probably about 1200° to 1250°. The difference of temperature is high, and there is a correspondingly rapid flow of heat, but as T_2 increases and the furnace temperature T_1 becomes slightly less, the difference becomes less and the flow of heat slackens until the normal difference $T_1—T_2$ is arrived at. We assume 1110° for T_2 and 1200 to 1250 for T_1, as in the previous paragraph.

The difference of temperature should be determined with carefully standardized thermo-couples and a recording instrument, both temperatures being taken concurrently, and the temperature chart would also show the

comparative value of K at different ranges of temperature by indicating the comparative rate of progression of T_1 and T_2 at say from 100° to 400°, 400° to 800°, and 800° to 1200°.

Leaving out of consideration questions of faulty manufacture and irregular heating of the retort from badly designed furnaces, if the furnace is worked excessively hot so that heat accumulates to a sufficient extent in the retort, the latter is softened, and if it does not collapse will become so dense in structure that it may crack later when cooled by recharging. The accumulation might take place at charging time by having the furnace too hot if the conducting power, K, was low, thus causing the heat to accumulate.

REPLY TO E. P. PAGE ON THE CONDUCTIVITY OF REFRACTORY MATERIALS.

BY

H. A. WHEELER, St. Louis, Mo.

The criticism that the method of testing the slabs of gas retorts was lacking in the refinements of an exact scientific test is quite true, but as the tests were on commercial material for commercial purposes, the results, to be of practical value, should come within the range of working conditions. This was the basis on which the tests were made, and duplicate determinations checked satisfactorily. Needless refinement was uncalled for when different parts of the same retort varied materially in thickness, varied appreciably in texture and grog constituents, while the source of heat supply, whether in a test or practice, varies so markedly in different parts of the flame. The aim, therefore, was to make all the tests under identical conditions, and thus obtain a *relative comparison* of the different samples under the same conditions.

This brought out an interesting and valuable range in the *average* heat conductivity of the different retorts tested. The results are comparable to the commercial determination of the moisture in a clay, when we would say 5.3%, whereas a scientist would report it as 5.323%; but the latter statement would excite amusement rather than impressiveness in an experienced engineer, when the practical difficulties of sampling are considered.

In the general but elementary formula quoted by Mr. Page,

$$H = \frac{A\ T\ K}{C}(T_1 - T_2)$$

we will, for simplicity, represent $T_1 - T_2$ by D, when we have:

$$H = \frac{A\ T\ K\ D}{C}$$

As under the conditions of the tests A, T and C were constant, this reduces for sample "m" to $H = K\ D$,
and for sample "n," to $H_1 = K_1 D_1$.

Comparing the heat transmitted by two samples "m" and "n," it will be mathematically represented by the expression:

$$H : H_1 :: K\ D : K_1\ D_1.$$

As D and D_1 were determined, we have: $H : H_1 :: K : K_1$, which was the information sought and given in the curve, as the latter was thought to be the simplest and clearest manner of expressing this information.

For it is self-evident that if one brand of retort "m," with the same thickness and under the same conditions as retort "n" has a greater heat conductivity, it will be more valuable to the gas maker since it will work off its charge more rapidly, will produce more gas in a year, and proportionately reduce labor and fixed charges as its ability to transmit heat exceeds that of brand "n."

DISCUSSION ON BLISTERING AND THE FINE GRINDING QUESTION.

BY

THOMAS GRAY, East Boston, Mass.

In regard to blistering, in Volume II, p. 139, Mr. Burt lays great stress on gases and air bubbles. I consider that our trouble came from cooling the kiln so quickly that the glaze was caught in a boiling, bubbling condition without giving time to "smooth out," for some pieces came out with the bubbles just ready to break, while others just showed that there had been a blister.

We always, until a year ago, fired to cone 8 (we now use cone 7) and pulled the fires out immediately after completion, and we seldom had any blistered ware. Our new superintendent, although not taking so radical a course, allowed the kilns to cool as rapidly as possible without drawing the fires. We found considerable blistered ware, and concluded to try soaking the kilns with a more gradual reduction in the cooling, and the result was very satisfactory. We use soft coal and cone 7.

For a number of years we have used flint from Mystic, Conn. We have not always found it finely ground. We used, up to a year ago, 120 lawn and ground our glaze 30 to 40 hours, and for the last fifteen years we have seldom seen a crazed piece of our stock. In January, 1904, we changed our superintendent and continued to use our old mixture, but as a new screen which we had just put in gave us too much "knockings," and we found it difficult to get our slip through, we changed our lawn to 100. Soon after we began to find crazed ware. There was more in some kilns and less in others. Some pieces were badly crazed and the greater part of the ware would craze in time, as we found to our cost. About August, after reading in Volume II Mr. Walker's remarks on fine grinding, p. 126,

Griffin, p. 135, Burt, p. 139, I concluded to try a coarsely ground glaze, and therefore cut the grinding down to 18 hours. Whether that was the correct solution of our problem I do not know, but we have had no more crazing since. I cannot find anything similar to our case in the articles alluded to, and as Mr. Griffin says he hopes the subject will be continued, I give the results of my experience.

THE CALCULATION OF THE COMPARATIVE FINENESS OF GROUND MATERIALS BY MEANS OF A SURFACE FACTOR.

BY

ROSS C. PURDY, Champaign, Ill.

Much has been written emphasizing the fact that the fine grinding of materials plays an important part in the manufacture of pottery bodies. There was, however, no means of expressing numerically the comparative degree of fineness of different samples until Mr. Jackson published[1] a formula by which he obtained a surface factor.

Mr. Jackson's idea is admirable and helpful, but his method of calculating the "surface factor" is so unnecessarily complicated, and the "surface factor" so large and uncomparable, that it has been thought expedient to offer in its place a simpler method, and one which will at the same time give a smaller and more consistent factor.

Development of Formula.

In Mr. Jackson's development[2] of the formula, he introduces a specific gravity factor, and defends[3] the introduction of this factor by a supposition which is true in itself, but which has no bearing on the "surface factor" as obtained. This is shown by the fact that it is eliminated in the development of the formula.

Therefore, it is not necessary to the truth of our method that the specific gravity of the various materials must be as nearly as possible the same, in order to allow of comparison with their surface factor.

In Mr. Jackson's arguments he has lost sight of the function of the Schoene apparatus. This apparatus is not designed to separate a given material into groups of particles classifiable by the velocities required for their elutri-

[1]Trans. Engl. Ceramics Association, Vol. III, p. 16.

[2]Trans. A. C. S. Vol. II, p. 173. Ceramic Calculation by W. Jackson, p. 22.

[3]Trans. English Ceramic Association, Vol. III, p. 21.

ation, but rather into groups of particles classifiable by their size. To accomplish this end with materials of different specific gravities, different velocities must be used, but the final report of the analysis is in percentage amounts of particles of different sizes of grains.

Further, in the development of the formula it is as logical to consider volume and surface as it is to consider mass and surface, i. e., leaving out the specific gravity factor altogether.

Development of the Formula.

The relation of the diameter of the assumed spherical grains to their surface is logically developed as follows:

Let D and d be the diameters of two spherical particles. Their volumes are respectively:

$$\frac{3.1416D^3}{6} \text{ and } \frac{3.1416d^3}{6}$$

In unit volume containing a group of these spheres there will be:

$$\frac{6}{3.1416D^3} \text{ and } \frac{6}{3.1416d^3} \text{ particles.}$$

The surfaces of the particles with diameters D and d are $3.1416D^2$ and $3.1416d^2$, respectively. Hence the total surfaces of each group of particles, per unit volume, are:

$$\frac{6}{3.1416D^3} \times 3.1416D^2 = \frac{6}{D}$$

$$\frac{6}{3.1416d^3} \times 3.1416d^2 = \frac{6}{d}$$

Therefore the ratios of the surfaces are:

$$\frac{6}{D} : \frac{6}{d} = \frac{1}{D} : \frac{1}{d}$$

or the surfaces per unit volume are inversely as their diameters.

Heath has shown that the same ratio can be obtained when the particles are assumed to be cubes.

Excepting the introduction of the specific gravity factor in the formula, I cannot see but that Mr. Jackson has given us a very simple means of comparing, numerically, the fineness of grain of our pottery materials. This factor does not give the actual sum of the areas or surfaces of the particles, but it does give numbers which are proportional to the actual areas. These numbers, which he has termed surface factors, are inversely proportional to the mean or average diameters of the particles, hence to obtain these factors it is only necessary to invert the value of the diameter, i. e., $1 \div D$.

$1 \div D$ gives the relative surface value or surface factor for the groups or particles having that average diameter. The surface factors for each group of particles are then multiplied by the percentage amounts, by weight, of each group in the whole sample, and the sum of the products thus obtained is the total surface factor for the sample analysed.

Errors in Mr. Jackson's Method of the Calculation of Surface Factors.

There are two errors in Mr. Jackson's method of calculation:

First. In the method of obtaining the surface factor from the expression $1 \div D$.

Second. In the calculation of the total surface factor for the material analysed.

The second error should perhaps not be noted by so strong a term as "error," for it is simply that he considers each group as a portion of 100 parts of the material instead of a fractional part of unit quantity. If 30% of the material analysed had a surface factor of 100, he obtains the surface thus represented by multiplying 100 by 30, whereas in similar calculations it is customary to multiply 100 by 0.30.

The first mentioned error, however, is correctly termed. It lies in the fact that his surface factors are not

consistent from problem to problem, as will be shown. This arises from the fact that he is not content to take the inverse of the diameters direct, but first multiplies them by some factor which will make them all whole numbers; then inverts them and reduces the fractions thus obtained to those having common denominators. The numerators of these calculated fractional numbers he uses as his surface factors. It is very evident that the value of each factor thus obtained will vary if the diameter of any one of the groups varies. That is, the value of the surface factor for a group say, having an average diameter of 0.0325 mm. for instance, may in one case be 448 and in another 518. This was shown very strikingly in Mr. Krehbiel's calculations.[1]

The Proposed Method. The simpler method of calculation here proposed is to invert the mean diameter of each group. Then to obtain the total surface factor, multiply the surface factor of each group by the fractional amount of the quantity of the sample having particles of these mean diameters. By this method the surface factor for a group of particles having an average diameter of 0.0325 m.m. will always be 30.769, irrespective of what the diameters of the other groups may be. Such a factor would be consistent, no matter how the sample was analyzed or what the mean diameters of the various groups proved to be. It would allow of comparing by surface factors Mr. Krehbiel's mechanical analysis of flint and feldspar with those of Mr. Jackson. At present this is not possible.

To make Mr. Jackson's surface factors consistent from sample to sample, the elutriating apparatus would have to be calibrated to wash out particles having given mean diameters. To do this with materials that vary in their specific gravity would be very tedious. Further, every experimentor would have to obtain the same sized particles from all somples. On the other hand, these very exacting conditions are entirely eliminated by the proposed method.

1. Trans. A. C. S. Vol. Vol. VI.

The following examples are given to illustrate and compare the two methods:

Example 1. (*See Vol. VII, p.* 179, *A. C. S.*)

Average diameters of each group, in m. m.	Jackson's Surface factor.	Proposed Surface Factor.
0.0800	182	12.500
0.0325	448	30.769
0.0175	832	57.142
0.0050	2912	200.000

The calculations employed in this problem are:

First. By Jackson's method:

$$0.0800 \times 10000 = 800$$
$$0.0325 \times 10000 = 325$$
$$0.0175 \times 10000 = 175$$
$$0.0050 \times 10000 = 50$$

$$\frac{1}{800} = \frac{182}{145600}$$
$$\frac{1}{325} = \frac{448}{145600}$$
$$\frac{1}{175} = \frac{832}{145600}$$
$$\frac{1}{50} = \frac{2912}{145600}$$

The surface factors are then 182, 448, 832, and 2912 respectively for each group.

Second. By the proposed method:

$$0.0800 = \frac{8}{100} \text{ and } \frac{100}{8} = 12.500$$
$$0.0325 = \frac{325}{10000} \text{ and } \frac{10000}{325} = 30.769$$
$$0.0175 = \frac{175}{10000} \text{ and } \frac{10000}{175} = 57.142$$
$$0.005 = \frac{5}{10000} \text{ and } \frac{10000}{5} = 200.000$$

The surface factors are then 12.5, 30.769, 57.142, and 200 respectively for each group.

Example 2. It is desired to compare two flints by their surface factors. The only point of difference in the results of the mechanical analysis of these two samples was in the average diameter of the particles of the first group.

One of the flints analyzed as given in example 1, the other as follows: (See Vol. VII, p. 175, A. C. S.)

Average diameter of each group in m. m.	Jackson's Surface factor	Proposed Surface factor.
0.1850	91	5.405
0.0325	518	30.769
0.0175	962	57.142
0.0050	3367	200.000

The methods of calculation in this example are the same as those employed in example 1, except that Jackson's factors were divided by 2. This was done to conform with Jackson's calculation. This fact alone shows the impossibility of Jackson's factors being consistent from case to case.

Noting the surface factors for each group, it will be seen that for groups having the same average diameter the surface factors by Jackson's method are very different, while the proposed factors for the group having the same average diameter are the same. Now by definition, the surface factor represents the relative surface of the particles per unit volume. Is it rational or consistent to allow a factor of 3367 in one case and 2912 in another, where these factors are supposed to represent the surface particles having the same average diameter?

In the following curve there is shown the relation existing between the diameters and the surface factors, according to the proposed method.

The curve is symmetrical to both the x and y axis and parabolic in form, having the equation:

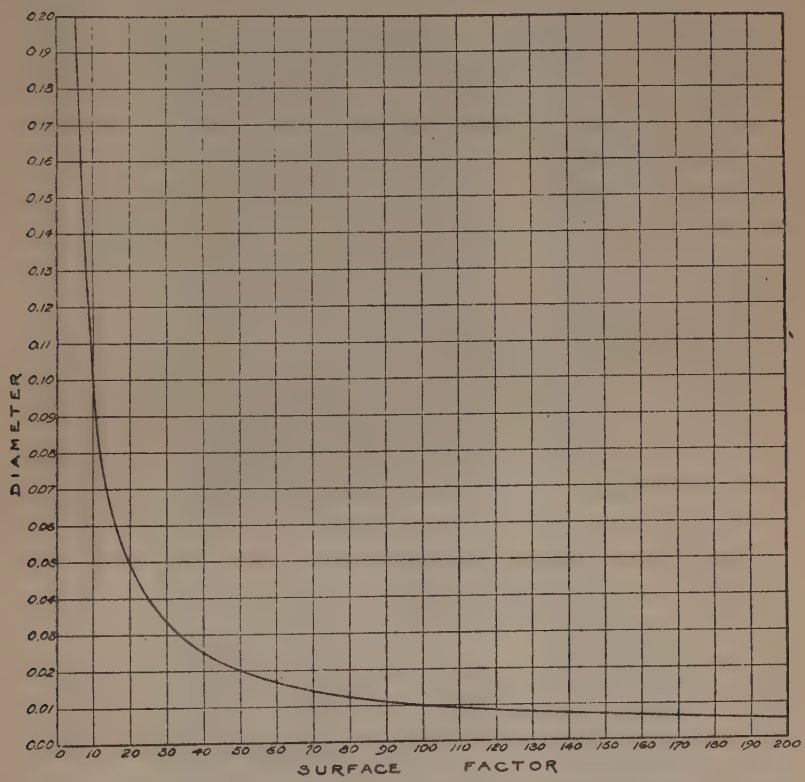
$$xy=1.$$

The curve is not presented to make easier the calculation of the surface factor, for that would be impossible. It is presented rather to show the constancy of this method.

It would be impossible to draw a curve showing the relation between Jackson's surface factors and the diameters of the grains.

The question at issue in this discussion is so important that the various points have been discussed at greater length. The inconsistency of Jackson's method was so

evident in Krehbiel's paper that at first it would seem that this lengthy discussion was uncalled for. But the writer's aim has been not only to point out the errors in Jackson's method, but also to show how simple a matter it would be to express the various grades of fineness of grain by a factor.



Curve showing relation between diameter and surface factor of grains.

A factor that presents difficulty in calculation or is inconsistent from sample to sample, would never be adopted by the potters and millers, but a simple one as obtained by the proposed method furnishes a basis of comparison that will fill a long felt want, and one which may be adopted.

SUPPLEMENTARY NOTES AND CORRECTIONS TO "ACTION OF REFRACTORIES UNDER LOAD CONDITIONS," VOL. VII, PART I.

BY

LEMON PARKER, St. Louis, Mo.

It is of importance in connection with the behavior of gas retorts in practice to note that benches of 8 or 9 retorts alone give trouble, due to their necessarily crowded arch with its contracted heat passages, and the placing of piers with heavy loads in the very hottest part of the flame, with no means of shielding them from the direct blast. Benches of 3, 4, 5 and 6 retorts seldom fail although exposed to the same flame chamber heat. This is due to the fact that the flame chamber is wider and more open on top thus minimizing the danger of softening from the confined heat.

With reference to the working temperature of gas retort furnaces, it may be said that all gas men claim about 2200°F as their working temperature.

In regard to Mr. Binn's question as to the enormous load required to crush a brick-shaped test piece, it might be added that though this is true, still the pressure would not be over 15 pounds to the square inch at 2700° and above. A pier 7″x9″ in floor area, or 83 square inches, and only 8″ high, after a year's service with a 15 pound load to the square inch has been known to soften enough to crush, the temperature of the furnace being not known, but being probably beyond the limit of safety.

This crushing or mashing, however, is a very slow process, ranging from six months to three years, according to conditions.

In answering Mr. Wheeler's question I might have said that at a given temperature three samples of the same mix set in the same kiln, loaded with a 2.5, 5 and 7 pound weight per inch, carried to say 2900°, showed a graduated compression of 0.13, 0.24 and 0.48 inch, thus showing that

the amount of compression increases with an increased load, temperature and time of exposure being the same in each case. These results have been affirmed by several triple tests.

In regard to the chemical composition of fire clay wares it is of interest to note that a very refractory St. Louis brick, with 64% of total silica but low in fluxing impurities, begins to become dense at a low temperature, say 2300°F, and is ordinarily burnt to 2400° in its manufacture. The failing point of this brick before actual distortion or appreciable fusion is over 3000°, it therefore is capable because of its density and hardness of carrying a very heavy load when cold.

A more refractory brick made from flint or aluminous clay does not become dense in this sense even at 2600°, and does not completely fuse until over 3300° are reached. This brick is very friable, and where proper mechanical manipulation is not gone through with is very liable to be crushed with a small load per square inch.

I incline to the opinion that a flint clay brick will be the best load carrier at a temperature beyond 2400°, while below that point the silicious brick would prove in a marked degree the best. I wish here to quote several authorities who touch upon this point indirectly.

Berthier, referring to his experiments on the action of heat upon mixtures of silica and bases, is quoted as saying,* "The addition of a very highly refractory substance like silica, or of an infusible one like graphite or coke to a clay, may not only tend to counteract the evil due to the contraction of the clay, but also fulfills another important purpose.

Crucibles composed of good fire clay may be softened and lose their shape at the highest temperatures occasionally produced in furnaces. In such cases the presence of one or the other of the above substances may act the part of a rigid skeleton tending to prevent its collapsing."

* Percy's Metallurgy, page 112.

According to Berthier, however, if silica be employed it may by long exposure to high temperature gradually enter into combination with the clay, forming a more or less homogeneous mass; and this will likely occur especially if the particles of silica are too fine.

Heinrich Ries says: "Quartz acts as a flux at a high temperature, but at lower temperatures it behaves as a refractory agent. If the clay is very low in fluxing impurities, and contains alumina and silica as its two chief elements, the refractory nature of the silica up to a high temperature will assert itself more strongly, but above that temperature, which is about 2800°F, the silica will flux the alumina. Therefore, in any clays that are to be used for refractory wares, an excess of silica is undesirable."

Bischof* expresses himself in regard to certain experiments made by him with mechanical mixtures of alumina, with increasing portions of very finely powdered quartz which were heated until fusion took place, by noting the following results: All specimens were fired to a temperature required to form silicates, by which is meant the change from the friable form to one appearing dense with an incipient glassy surface, and held there Those tests with most silica required the longest time for the change to the silicate, corresponding to the increase in silica in various specimens The heat employed was the fusion point of cast steel, 2500°.

When the heat was raised to the melting point of wrought iron, 2700°, and higher, so as to change all specimens to silicates in a very short time, an increase in silica gave a more liquid combination.

Corrections Referring to the Article on Page 185, *Part II, Volume VII, of the Transactions.*

Page 186, fifth paragraph, second line, should read "They showed a heat resistance of 3132°, before fusing enough to have the appearance of the tile that were destroyed in use at the gas works."

* Die Feuerfesten Tone, page 53.

Page 187, second and third line, of the last paragraph. Here Mr. Parker is made to say: "Will sustain considerable loads when cold." This should read: "From 600 to 3000 pounds per square inch when cold."

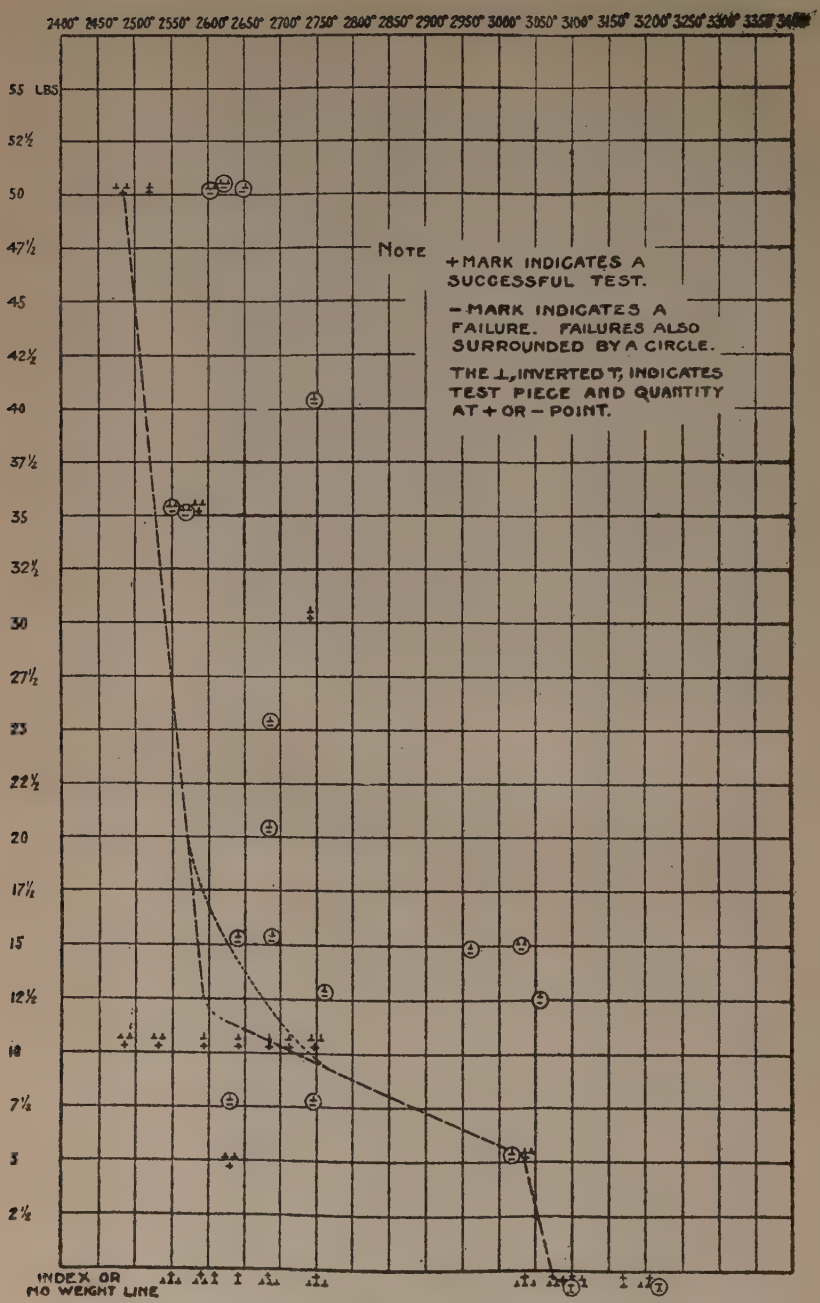
On page 186, second paragraph in the fourth line the words "Most intense heat" should read, "The most intense heat of any of the three forms of the calcium light."

In the second line of the third paragraph, page 186, the word "calcium light" should read "oxy calcium light," that being the particular form of light referred to there.

Page 199, third question: Mr. Wheeler asks what kind of fracture was noted, whether a vitrified fracture. In reply I probably said, that if we have a low heat we will not have a vitrified fracture, but if we have a high temperature we would find a vitrified fracture.

In answering the last question on page 199: What is the size of kiln, asked by Mr. Wheeler on page 200, I am made to say that the depreciation seemed to be accordingly. I probably said that the compression seemed to be accordingly.

In preparing the cut for the above article some omissions have ben made in the diagram, Fig. 2. The accompanying diagram should be substituted for Fig. 2.



Curve showing relation between temperature and ability to withstand crushing strain.

REPORT OF COMMITTEE ON CERAMIC LITERATURE

CHARLES F. BINNS, Chairman.

ENGINEERING NEWS.

Reported by Harrison Everett Ashley.

(1905, 7, 20), 54, [3], 63.

Low Pulling Early Stage Portland Cement vs. The Ordinary Early Strength Developing Product. W. A. Aiken. 1200 words.

(1905, 7, 13), 54, [2], 35.

Investigation of the Effect of Heat upon the Crushing Strength and Elastic Properties of Concrete, Ira H. Woolson. 5000 words.

(1905, 8, 24), 54, [8], 204.

An Interpretation of Recent Tests on the Fire Resistance of Concrete.

(1905, 8, 24), 54, [8], 208.

The U. S. Government Cement Plant at the Roosevelt Dam, Arizona.

(1905, 8, 31), 54, [9], 211.

The Manufacture of Sand Lime Brick (by a plant constructed by the American Sand Lime Brick Co., Chicago).

(1905, 8, 31), 54, [9], 23.

F. W. Hagloch. The Manufacture and Use of Concrete Blocks.

(1905, 9, 7), 54, [10], 238.

Edwin C. Eckel, Specific Gravity and Weight of Building Stone, Cements, and Other Non-Metallic Structural Materials.

(1905, 9, 7), 54, [10], 252.

Reinforced Concrete Construction in Freezing Weather.

(1905, 9, 21), 54, [10], 254.

Edgar James Banks, The Evolution of the Babylonian Brick.

(1905, 9, 21), 54, [12], 300.

Richard L. Humphrey, Cement and Cement Concrete Tests at the St. Louis Exposition. (Important.)

(1905, 9, 28), 54, [13], 324.

Alexander R. Binnie. The Expansion and Contraction of Concrete, (4:1 expands 0.00005226 inch per foot, per 1°F).

BULL. DE LA SOC. D'ENCOURAGEMENT.

(1905), 107, [6].

Revue de Metallurgie, pp. 441-470. The Fusibility of Blast Furnace Slags, O. Boudouard. This paper will appear in full, in English, in the forthcoming number of the Jour. Iron and Steel Institute. It has been quite fully abstracted in Engineering and Mining Jour., May 25, 1905, and Jour. Soc. of Chemical Industry, June 30, 1905.

(1905), 107, [7], 914-937, from Elektrochemische Zeitchrift, 1904 and 1905, pp. 144, 167, 185, 205.

The Melting of Glass by Electricity, and Heating by Means of Divided Conductors (Kryptol), M. Bronn. 43 figures in text.

The author gives a historical account of the various devices for melting glass by electric arc furnaces, and of his own experiments, in which the discoloration from carbon taken up by the glass from the electrodes, whatever the arrangement, proved fatal to success.

The second stage was the use of arcs to heat the exterior of crucibles, or the interior of porcelain tubes. In the latter case the charge to be melted was put upon a grating of tubes, each heated by an arc inside.

The final step, "Krytol," is the author's invention of a resistance furnace, consisting essentially of fragments of carbon. These fragments, specially prepared, have greater resistance than solid carbon, and develop heat throughout their mass instead of locally, as with solid electrodes; nevertheless the current (consequently the heat) can be concentrated at any region desired by introducing solid carbon blocks, or kept away by insulating shields. Crucibles, muffles, tubes, etc., may be heated.

"It was still necessary to make a great many tests and measurements, to be able to make the furnace work at normal tensions of 100 volts and more."

"The nature of our resistance, which received the name of Kryptol, its degree of fineness, and the connections have an essential importance. The work most difficult of attainment was the construction of each new apparatus so that it could be regulated without interposing intermediary resistance."

"In certain furnaces, it has been possible to regulate temperatures from 1600-1700°, with a precision of 10 to 15°. In working at these high temperatures, the nature of the refractory material employed and the nature of the current are of great importance. Although at temperatures running up to 1000°, the continuous or alternating and polyphase currents have no action on the granular resistance, it is not certain that it would be still the same at 1500°."

To the reviewer the apparent simplicity, adaptability, and rapid working of the Krytol furnaces for such high temperatures is very alluring. They are now imported by dealers in scientific apparatus. Their successful operation will require some thought and pains. One should not secure a furnace without first finding out just what amount and kind of electric power is required.

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